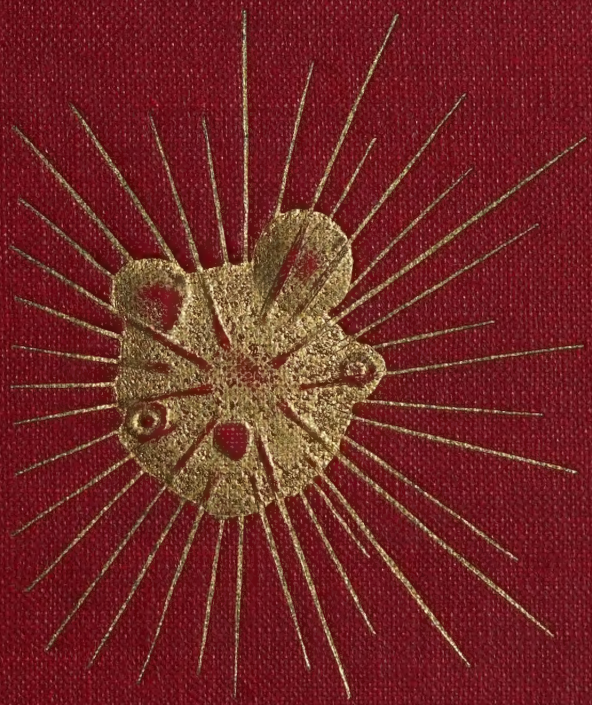
Social Biology

WALTON & FOSS



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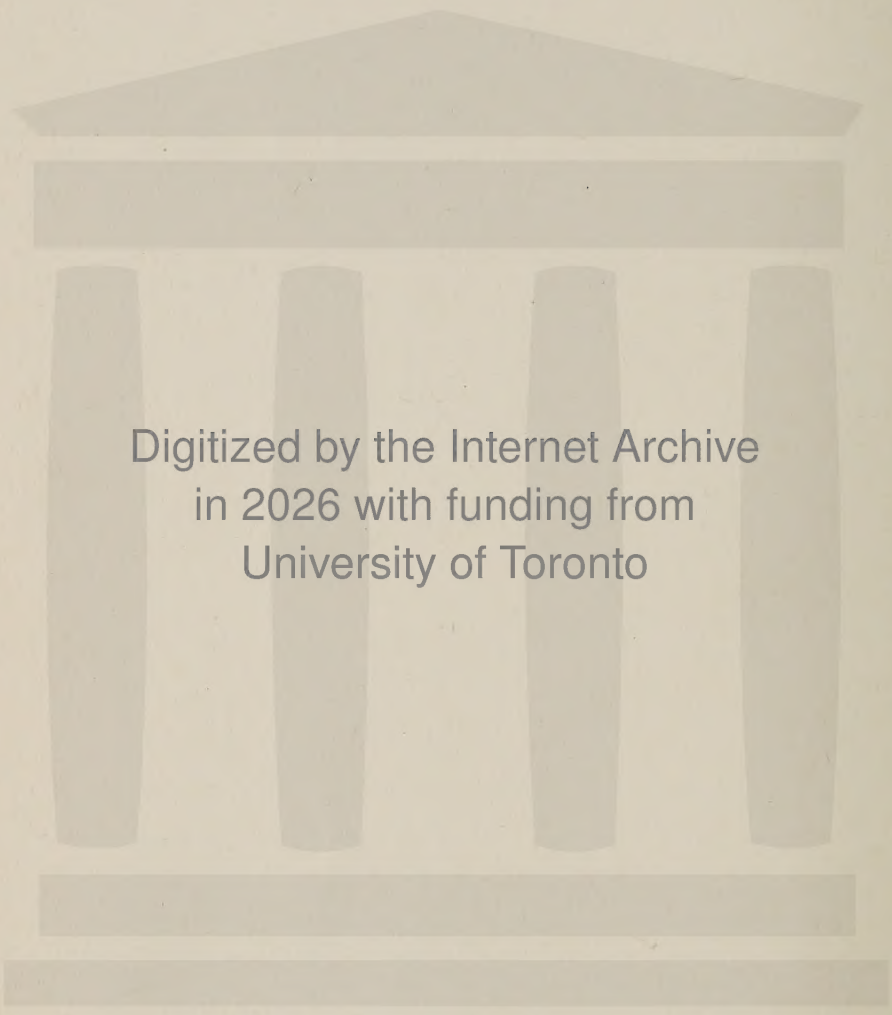
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SOCIAL BIOLOGY

A Textbook for Secondary Schools

(*Frontispiece.*)

Frontispiece. The General Sherman tree in Sequoia National Park. A century in the life of one of these sequoia trees is comparable to a year in the life of a human being. (*Atwood.*)

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SOCIAL BIOLOGY

A Textbook for Secondary Schools

BY
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AND
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THREE HUNDRED SIXTY ILLUSTRATIONS

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PREFACE

Biological science has attained with surprising rapidity an important place in secondary schools. Formerly its position in the curriculum was an inconspicuous one, but as the value of a scientific approach to problems of this scientific age became evident, attention was focused more and more on biology as the subject most intimately associated with the many problems of modern living conditions. It was noted as time went on, that more and more pupils were without college aspirations. These changes convinced educational leaders that satisfactory results could not be achieved with the methods then in use in high schools: that college courses, modified or simplified by college trained teachers, would not do for secondary school study.

Intensive research was instituted to discover methods of motivation which would result in the retention of essential values in the mind of the student. This research has borne valuable fruit, and is represented best, in summary form, in the report in Part I of the Thirty-First Yearbook of the National Society for the Study of Education, 1932. The authors are thoroughly in agreement with the conclusions of this committee, and believe that its report represents a distinct advance in the scientific educational field.

Our own experience leads us to believe that the best way to arouse interest in the mind of the adolescent boy or girl is by induction, and that a slightly imaginative appeal is essential for inspiring and maintaining that interest. In other words, it is not only a case of "leading the horse to water," but the water must be made to appear so attractive that a thirst will be induced, if one is not already present.

We believe that a pupil should leave the course with a thorough understanding of the unity of nature, and of man's place as a

part of that unity. With the development of this central theme constantly in mind, we have attempted to retain at their full value, such important concepts as the scientific method of approach to life's problems; the relationship between biology and the other sciences; and the practical application of biological facts.

It is obvious that the factual material in a book of this nature is a compilation largely derived from the published works of others; from the experience of years in the classroom; and from informal discussions. It is manifestly impossible to give individual recognition to the large number who have had such an indirect part in the making of this book, deserved though that recognition may be. Responsibility for errors that may appear must be laid entirely on the authors. Any values the book may have are largely due to the helpful cooperation of our colleagues in the biology department of our school, and of specialists in the various fields of biology who have aided us with a high quality of direct constructive criticism. Their names are inscribed below as evidence of our gratitude.

Thomas H. Bissonnette, Ph.D., Professor of Biology and Head of the Department, Trinity College, Hartford, Conn.

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Charles Z. Southard, Author of "A Treatise on Trout for the Progressive Angler," "Trout Fly-Fishing in America," and others.

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E.P.W.
P.E.F.

FOREWORD TO THE TEACHER

Biology often stimulates in many ways original and individual work by the pupils. With a little encouragement the members of the class willingly search for and bring into the laboratory, various plants, small turtles, salamanders, tadpoles, and other organisms. These contributions arouse interest, and help to relate the indoor work to the personal experiences of the pupil out of school.

Field work in connection with the activities of the class makes possible the development of collections designed for demonstration—a source of pride on the part of the class, and frequently useful in the hands of the teacher. To be most successful, however, field trips by the class should be carefully organized, each pupil having mimeographed directions calling for definite observations and a written summary. A bulletin board may well supplement the field work, and when supplied with clippings from current newspapers and magazines, provides continued interest. Pupils contributing to these activities feel that they have a more active part in the proceedings of the class.

The organization of a Biology Club, if one does not already exist, brings about a community of interest in the class work, which makes worth-while the labor of additional supervision. Many boys and girls will bring into their biology club activities an interest in some phase of nature study gained in connection with the Boy or Girl Scouts, or similar organizations. Pupils are quick to appreciate the value of systematic effort under guidance, and this, in turn, helps to develop more rapidly the habit of approaching all problems scientifically—a most valuable objective of any science course.

It is the belief of the authors that biology has a strong and direct appeal of its own when presented in a less austere and

formal manner than usual. This more informal presentation also offers greater opportunity for self-expression, and tends to correlate the experience of the pupils with the textbook matter.

The division of this book into units makes possible the transfer or omission of certain units, at the discretion of the teacher, or to fit the study to the season of the year. Some of the projects are too difficult, or require too much time for the class as a whole. These have been introduced to interest the more skillful or rapid workers. The more rapid workers will find the work more challenging, and it will add to the background of information of the class as a whole if they are encouraged to make special oral reports based on selected readings from the book list in the appendix.

If time permits a class to take advantage of the many opportunities provided by work in the field and library, in addition to the regular class activities, the pupils will carry away with them after completing the course, something of an understanding of the ways of living things, and a more scientific approach to their own problems throughout life.

E.P.W.
P.E.F.

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UNIT I

MAN IS ONE OF THE MANY KINDS OF LIVING THINGS

CHAPTER I

ALL LIVING THINGS ARE INCLUDED IN THE STUDY OF BIOLOGY

1. You are about to embark on an adventure, limitless in extent and more fascinating as you proceed. When adventuring into the realm of a more intimate acquaintance with life and living things, you will be impressed with the orderliness of nature's arrangements and processes as well as with the diversity of forms, each a unit of complexity and wonder. Your acquaintance with nature does not actually start now, of course. Ever since you first became aware of your surroundings you have been increasing this acquaintance. But it has been casual, probably, and most living things have been accepted as a part of the general background without thought or comment. Now, as a student in science, you are to delve deeper, and not take so much for granted. You will be expected to exercise your curiosity and seek reliable information from nature. You will also be expected to develop your ability to observe carefully, to record your findings with accuracy, and to approach general principles with understanding. Scientists have been doing just these things for a long time. The information is recorded in pamphlets and in books like this one, where you may obtain it more easily and quickly than would be possible if you had to discover the facts all over again. Then, if your interest is genuine, you will want to proceed into the unknown and glean new information to add to the general fund.

2. As biology is the study of living things—plants and animals—most of your attention will be directed toward these. However, as plants and animals are built of the non-living materials of the earth such as minerals, gases and water, you will need to know something of the things which are studied more thoroughly in the sciences of physics, chemistry and geology.

FIG. 1.—Information learned in the classroom and laboratory becomes more interesting when applied out-of-doors.

3. There are so many thousands of kinds of plants and animals that it is impossible for one person to become acquainted with all of them. Therefore, after sufficient general information is obtained, it is customary to specialize in the division of biology which one finds most interesting. For example, the student of bacteriology (*băk-tē′rĭ-ol′ŏ-jĭ*) studies certain minute plants and is known as a bacteriologist; the student of insect life is called an entomologist (*ĕn′to-mŏl′ŏ-jĭst*); the student of fruits and fruit growing is known as a horticulturalist (*hôr′tĭ-kŭl′tūr-ăl-ĭst*). But one should understand thoroughly the general principles underlying the whole science of biology before attempting any kind of specialization. In accomplishing this purpose you will develop valuable skill for any kind of work you may attempt.

Skill in observing carefully and correctly, skill in recording accurately, skill in organizing and classifying knowledge—in any

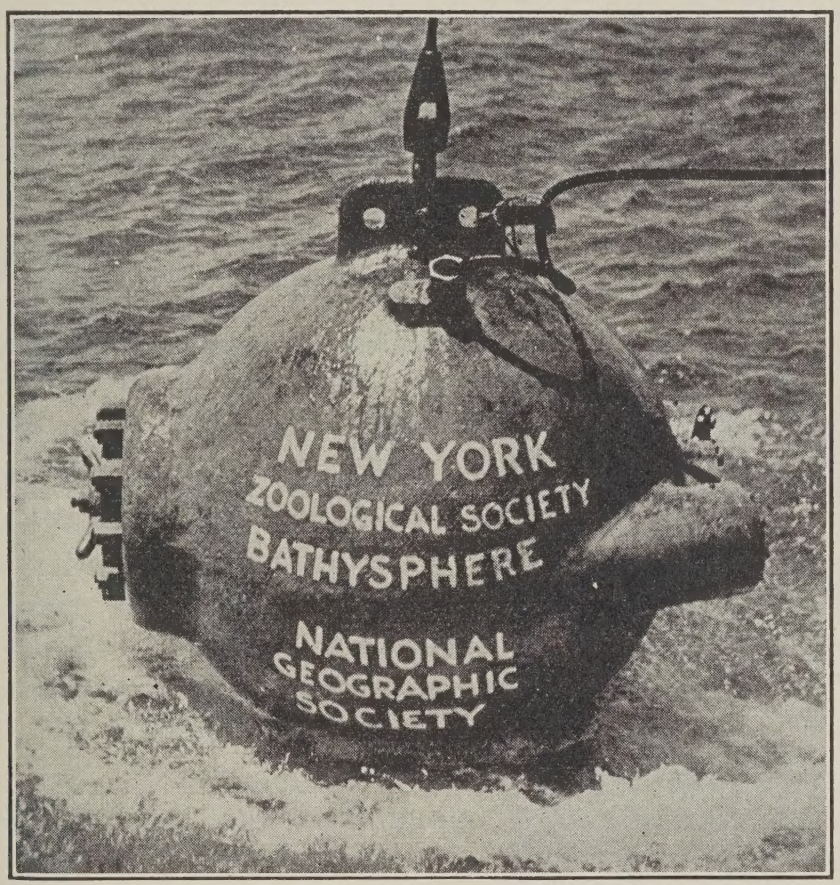


FIG. 2.—In this hollow steel sphere, built to withstand the enormous pressure of water far below the surface of the ocean, Dr. William Beebe and his associates have descended more than half a mile. In these cold and sunless regions many new and strange forms of life were discovered. Biology offers many forms of interesting work, sometimes accompanied by thrilling adventure. (*Courtesy Dr. William Beebe.*)

kind of the world's worth-while work you will find skill to be of first importance.

Interesting Projects

1. Look at the picture on page 425 for thirty seconds. Now close the book and describe all the details of the scene which you can remember in the picture. Look at the picture again to see how many you left out. If your list includes three-fourths or more of the characters and objects, an ability to observe carefully and accurately is indicated.

2. Make a list of plants and of animals living around your school and home. Arrange these carefully in a tabular form under the two headings "Plants" and "Animals."
3. Make a list of common non-living things. What is the principal difference between living and non-living things?

Review

1. Define biology.
2. What are the characteristics of a successful scientist?
3. Why do many scientists become specialists in some field of biology?
4. Why does the biologist need to have a knowledge of physics, chemistry and geology?
5. Name several occupations which use knowledge gained from the study of biology.
6. Why is it necessary to obtain a general knowledge of biology before specializing in any one of its branches?
7. Why is it possible for us to know much more about any science now than would have been possible had we lived one hundred years ago?

Define

bacteriology
biology
chemistry
entomology
geology
horticulture
mineral
physics
scientist

CHAPTER II

THE STUDY OF BIOLOGY CONTRIBUTES MUCH TOWARD A WELL-ROUNDED LIFE

4. In these days of noise and confusion, as the country is again becoming speeded up in its recovery from the depression, there is a growing tendency to try to escape from these conditions and to get out into the country. But to do so without some understanding of the commoner forms of wild life and their ways of living, does not always bring the enjoyment that it should bring. With the coming of the automobile more and more people are getting out into the country and are learning to see the beauties of nature and are coming to appreciate, more than ever before, the wonders of the great out-of-doors. But to appreciate nature at her best, one must really know something about her.

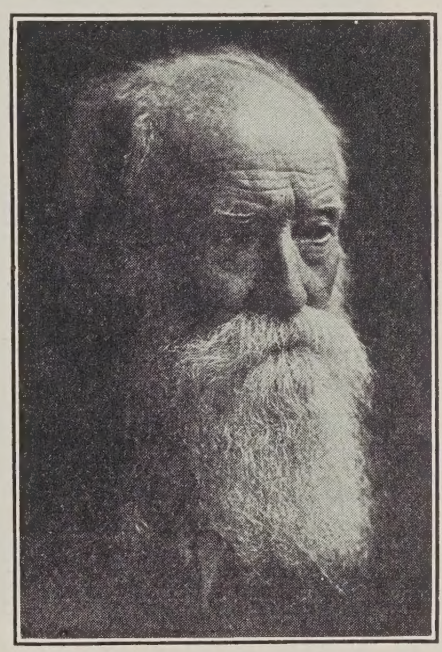


FIG. 3.—John Burroughs (1837–1921), through his writings called the attention of thousands of young people to the beauties of nature. (*American Museum of Natural History.*)

5. The study of biology will, probably, do more for you than any other subject that you will study, in opening the doors of nature and in leading you out into the fields and woods where so many beauty spots are to be found, where plants and animals alike are living their lives, and where we too, in relaxation, may live ours more fully.

6. Getting Acquainted with Living Things.—The great naturalist Agassiz said, "Study nature, not books." But that was long

before all the wonderful books on biology which we have today were written. Now we say, "Study nature **and** books." Your biology will open a new world to you. The famous scientist Pasteur must have felt this need of first-hand knowledge while studying under his microscope those various kinds of disease

FIG. 4.—The study of biology will help you in opening the doors of nature. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

germs which he had never known before, when he spoke of "the world of the infinitely little."

7. A new world of living things was opening right before his eyes. This experience will be yours, also, as you go on with your study of biology, learning how your own body is built and how the different parts work; recognizing the fundamental life processes that are carried on by every living thing—what its problems are, its struggles, and discovering how science is lengthening human life by overcoming sickness and disease;

and how our great natural resources are being saved after long periods of misuse—these and many other interesting subjects will claim your attention, in your study of biology.

8. Perhaps some morning we see a Mourning Cloak, that first of all the early spring butterflies, and wonder where it came from, where it spent the winter, and whether it has just hatched or has lived throughout the winter as an adult. We wonder what it feeds on if it does eat, and before we realize it we get interested

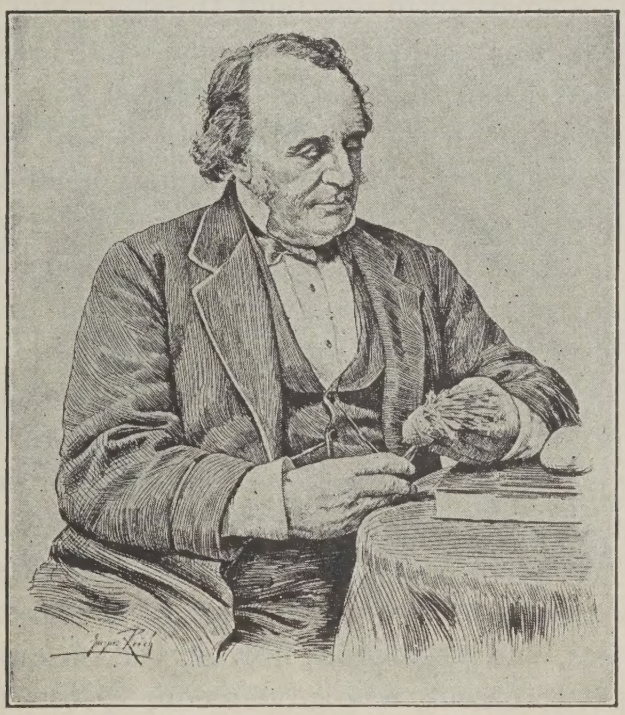


FIG. 5.—Louis Agassiz (1807–1873), former professor of zoölogy at Harvard University, was a pioneer in introducing into America the laboratory method of studying biology. (*Corwin and Corwin.*)

in butterflies and moths. The next thing we see is some plant that is dying because an insect larva has stripped it of most of its leaves, and we wonder about that—what insect it was, what it looked like, and whether we have ever seen one somewhere. Then we want to learn about these forms and thus satisfy our curiosity. Or, if the season is spring, we hear the first spring peepers. Someone tells us that they are Pickering's Hylas, one of the smallest species of all our native frogs, cousins of the tree

frog that lives in trees and is so difficult to see. And maybe we wonder how they can spend the whole winter down in the mud at the bottom of that pond or swamp. We do not see how they could breathe there.

9. What a thrill I got one evening a few years ago just at twilight, when I saw in a little clearing in the Maine woods, thirteen wild deer all feeding there at the same time! You would have felt a thrill too, had you been there with me. Since then I have been reading more about the deer; how they live and where they live, what they feed on, and what time of day they feed; not because I had to, but because I just wanted to. In the same way your interest will be aroused, as you go on studying these living things, for they are what biology is all about.

10. What the World Owes to Biology.—The world owes so much to biology that it is impossible to mention here more than a small part of it. Our lives are safeguarded by the work of Lister, who gave us aseptic surgery, which led to the use of antiseptics in general; to Pasteur, who developed the treatment which we use today for hydrophobia, and also proved that many diseases are caused by microscopic living plants and animals called germs. To Jenner, who is the father of vaccination, we owe much. We also owe much to Luther Burbank and the other plant breeders who originated many of the different kinds of fruits, berries, and vegetables now served on our tables. We must not forget Linnaeus, who gave us our system for classifying all living things. There are also many other famous men. Who built the Panama Canal, only the men who actually did the excavating? It was a biologist, Surgeon-General Gorgas who, by controlling the malaria and yellow fever, made it possible for the excavating gangs to work there.

11. You have, no doubt, read about witchcraft and the suffering that it caused. Are you not glad that you live in an enlightened day and that we are free from such superstitions? Have you ever thought that this enlightenment is the result of the truths about living things which men have learned through biology? Today, only the ignorant are superstitious.

12. Vocational Opportunities.—In every state of the Union men and women who are trained in biology are holding responsible positions under the federal, state, and municipal governments. The United States Biological Survey employs dozens of trained workers in its various branches. Hundreds of men who prefer to live out of doors find in the Forest Service the work they enjoy most. Likewise the United States Fish Commission

FIG. 6.—Men at work in the U. S. Forest Service. (*Photo by U. S. Forest Service.*)

employs a great many persons. There is need of trained workers in the large biological museums of many cities and the National museum at Washington. Hundreds of such persons now serve in the teaching profession, in the field of Biology.

13. When I was a student at college, my attention was centered for a moment every morning as I entered the biology laboratory, on a bronze tablet which stands as a tribute to a great man:

"A student and interpreter of Nature,
A teacher, faithful and beloved,
A friend and helper of men."

Do you see anything of a challenge in these words? The world is looking for young men and young women in the many

fields of biology—people of sound training, such as was Professor Lee, to whom the above words were inscribed. It is looking for those with alert eager minds, active from habit, who desire not only to serve, but to keep on learning about the ways of living things.

Interesting Projects

1. From your school or public library get the "Life of Louis Pasteur" and report to the class the problem with which Pasteur was engaged at the time he voiced the famous expression given in paragraph 7 of the foregoing chapter.
2. Make a list of the different kinds of birds, trees, insects, flowers and other living things which you find in a one-hour trip through the park or fields and woods.
3. Give a class report showing the growth of public interest in state and municipal parks, and the remarkable increase in the numbers of such parks.
4. Report to the class about the belief in witchcraft as late as three hundred years ago, and the punishments inflicted upon those persons believed to be witches. Show how scientific thought has removed all these superstitions.

Review

1. Why are our observations out-of-doors likely to make us want to study about living things?
2. How may the study of biology make life more worth while?
3. Tell five contributions to biology which make our lives today safer and more pleasant.
4. Name five vocations to which one may be attracted because of his study of biology.
5. What type of mind is most likely to succeed in any scientific vocation such as the ones included in biology?

Define

antiseptics
aseptic surgery
germs
hydrophobia
insect larva
microscope
museum
natural resources
vaccination

CHAPTER III

THE HISTORY OF MAN SHOWS A PROGRESSIVE DEVELOPMENT

14. The written record of the happenings in the great human family is fairly complete and accurate from the time of the Egyptians. Original records from that early period, and earlier, are few, difficult to read, and fragmentary. Knowing the capacity of this early people to develop and to carry on an extensive civilization, it is evident that humans who lived even earlier must have had intelligence and ability. A realization of these facts has brought about the development of methods for determining the kind of life these earlier people led. Usually a study of their implements and their burial customs provide most of the evidence. The time involved is determined by a study of rock deposits. Thus there has been built up the belief that man first appeared as a definite kind of organic life at least fifty thousand years ago. When we consider that the Egyptians reached their highest prominence less than three thousand years ago, it is evident that there is a long period of human history about which we know little.

15. The only parts of the body able to persist for such a long time are the harder parts, such as the bones and teeth. Even these parts must be deposited in soil which later is to solidify into rock or otherwise be sealed from the air. With this protection, these structures, known as **fossils** (*fos'-ilz*), may continue indefinitely.

16. The methods for carrying on the activities of life, such as making implements of stone or metal, and the manner of burial show cumulative changes. That is, it is evident that information was handed on from one generation to the next, and that an increasingly complex culture developed.

17. When human families ceased to live as units, and banded together for better protection or for the purpose of waging war more successfully, the exchange of ideas resulted in a more rapid development of their culture. This process has continued

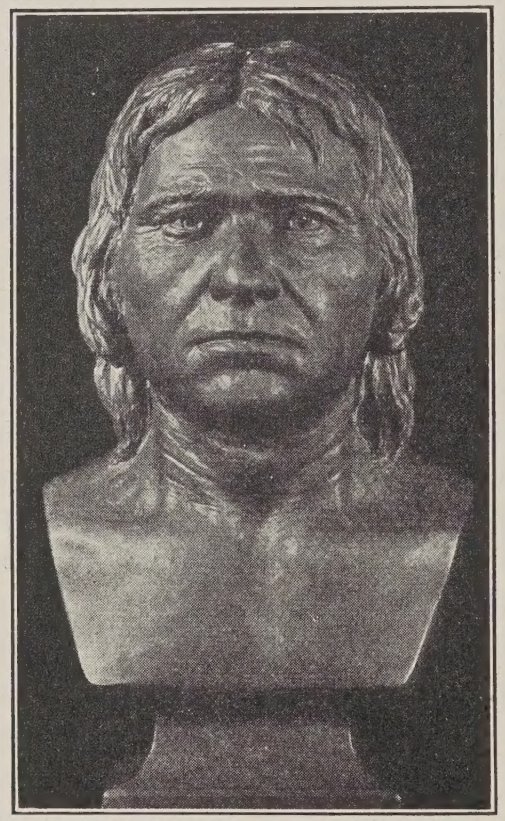


FIG. 7.—This man represents a race known as the Cro-Magnon. Many intelligent and capable groups of people lived before the dawn of history. (*American Museum of Natural History.*)

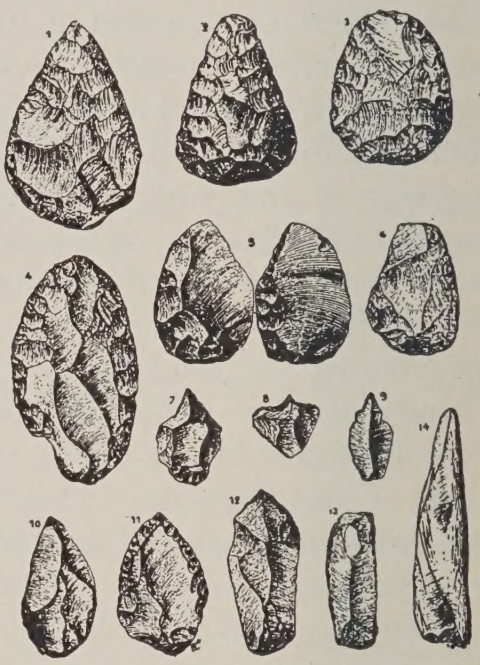


FIG. 8.—These implements represent man's early attempts to aid himself in getting food or in destroying his enemies. (*American Museum of Natural History.*)

through the centuries, so that now we must spend nearly a third of our usual life span in school, learning the important parts of this accumulated experience as it is recorded in books, in order that we may take advantage of it in our own lives.

Interesting Projects

1. Let one hour represent each thousand years of time; then determine how long the human race has been in existence according to this scale.

2. Learn from a book on geology what the three common kinds of rock formations are, and where they may usually be found. Find at least one specimen of each kind and bring all of them to school.
3. Make sketches of some of the more primitive implements used by prehistoric people.

Review

1. How is information obtained concerning people about whom there is no written record?
2. How have habits of living changed during the ages?
3. What advantages were derived by the formation of tribes; of states?
4. What modern inventions have aided the development of the culture of the world as a whole?
5. What are fossils? How is their age determined?
6. Why does the culture of a people become more complex as time continues?

Define

civilization **implement** **racial culture**
fossil **organic life** **rock deposit**

CHAPTER IV

MAN HAS FOUND A CLASSIFICATION NECESSARY IN STUDYING LIVING THINGS

18. Just as the grocer must arrange the goods on his shelves with care if he is to locate them quickly, so must the biologist

FIG. 9.—Carolus Linnaeus (1707–1778), a Swedish botanist, originated our modern system of classification. (*Atwood and Heiss.*)

classify the different plants and animals in groups, in order to know them and avoid utter confusion in his study of them. The basis of a classification is *structure,* those plants or animals most alike in the way they are made are placed in the same group.

19. Classification, or taxonomy (*tax-on'-om-e*), was an indefinite science from the time Aristotle (*ar'-is-tot'-l*) made a beginning centuries ago until the time of the Swedish scientist, Linnaeus (*lin-e'-us*) who lived from 1707 to 1778. By using the classical languages, Latin and Greek, which, being dead languages, no longer change, and by adopting a name consisting of two words for each plant or animal, he simplified the older arrangement in which a description was necessary.

FIG. 10.—The bobcat is similar in structure to the domestic cat, and is placed in the same family. (*Courtesy of Bates College.*)

20. If a stranger were to look for you as an individual, he would need to know both your given name and family name, your street address, the name of your town or city and state. If, on the other hand, you were to look for the name of a plant or animal, the process would be similar except that structure would determine the unknown name. For example, suppose you were to classify a cat. You would first determine that it was an animal, not a plant, and place it in the **animal kingdom.** The supporting skeleton being inside the body would place the animal in the

phylum Chordata (*kord-a'-tah*). The presence of hair would give you the **class Mammalia** (*mam-a'-le-ah*). Its structures for grasping and tearing fleshy food place it in the **order Carnivora** (*kar-niv'-or-ah*). Certain differences in foot structure, particularly, would help you place it in the **family Felidae** (*fe'-lid-e*) and **genus** (*je'-nus*) **Felis,** and finally the fact that it is a domesticated form gives it the **species** name **domestica.** It is customary to write the first letter of the genus name as a capital, while the first letter of the species name is a small letter. So you would finally arrive at the scientific name of your pet cat as **Felis domestica.** (*fe'-lis do-mes'-tik-ah*).

Interesting Projects

1. Following the method of this chapter, arrange a classification of the dog. You will find the family, genus and species in any large dictionary.
2. Look up in the encyclopaedia the life and accomplishments of Linnaeus. Write a brief review of his life and work.

Review

1. What is the science of taxonomy?
2. How does Linnaeus' classification differ from older ones?
3. Why is the classification of Linnaeus more convenient to use than were the older ones?
4. Why is the structure of a plant or animal used as a basis for classification, rather than appearance or method of living?
5. Compare a city directory with a biological classification.
6. Some persons think of the whale as a fish, but biologists have placed it in the same class with the bear, cow and man. How do you account for this?
7. In a scientific classification, why is classical Latin ordinarily used rather than one of the languages derived mostly from Latin, such as French, Italian or Spanish?

Define

animal kingdom
carnivora
chordata
class
classical language
classification
family
genus
individual
mammalia
order
phylum
skeleton
species
structure
taxonomy

UNIT II

THERE IS A BASIC SIMILARITY IN STRUCTURE AND FUNCTION AMONG ALL LIVING THINGS

CHAPTER V

THE CELL IS THE PHYSICAL UNIT OF ALL LIVING THINGS

21. We have all seen brick houses. Some of us have seen the bricklayers as they were laying the bricks, each one exactly placed. And as more and more bricks were added we were able to see the house grow.

Now this body of ours is, in a way, like that house. It started, like the house, with just one "brick", and grew as more were added. We do not call these units of our body bricks but **cells.** This term is at first a little confusing because we have always thought of a cell as a hollow space, while the cell of the living plant or animal is usually just as full of material as it can hold.

22. The Discovery of Cells.—Robert Hooke, in 1665, as he looked at cork bark under a lens and saw there many tiny holes, surrounded by walls, called these walled spaces cells; and, so far as the records show, that was the first time the word had ever been used with reference to the tiny parts of which living things are made.

23. Nearly two hundred years later two Dutch scientists were studying plant and animal tissues under a microscope, and each found out that the living bodies of plants and animals are made up of tiny parts, which, as unit structures, may be likened to the bricks in the wall of a house. They, too, called these parts cells. Thus that meaning has come down to us today to indicate

a complete whole, a unit—just the opposite from what Hooke meant when he first used the word. So cells are the units or the building blocks of which our own bodies are made.

24. What Cells Are Like.—The first biologists knew nothing about cells, because without the microscope they could not see them. No one knows who invented the microscope. Perhaps

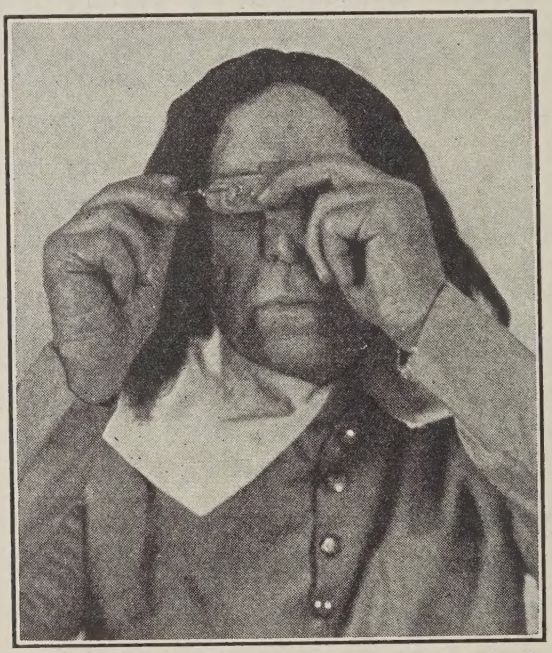


FIG. 11.—With an instrument like this, Leeuwenhoek discovered a world of plants and animals so small they had never before been seen. This is a photograph of a man dressed like Leeuwenhoek who is representing him with his microscope. (*Courtesy of Bausch and Lomb Optical Co.*)

like many other great inventions, it developed from the minds of several scientists. One of the earliest pioneers in its use was Anthony van Leeuwenhoek (*la'-ven-hook*) [1632–1725], who lived in Holland. He was not trained as a scientist and his work lacked the systematic purpose of later workers. But his interest was keen and he ground hundreds of lenses, tested them in various combinations, and did much to improve this type of instrument. The microscope made possible the discovery of cells by Hooke, and has increased our knowledge about them since that time.

25. Some bricks are used for one part of the house, such as the inner walls; others are used for the outside "facing" and must be

different to do work of a different kind. It is the same with the cells of living things. In our own bodies, too, there are many different kinds of cells to do different kinds of work, such as thinking, moving about, and supporting our bodies in an upright position.

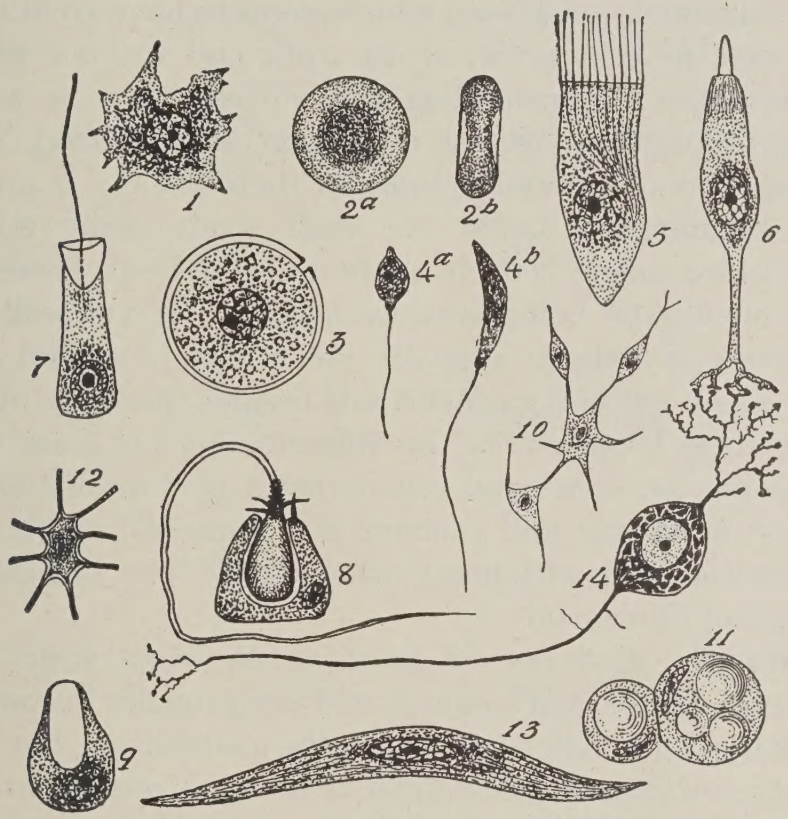


FIG. 12.—Types of cells. (1) Colorless blood corpuscles. (2) Red blood corpuscles. (3) Egg cell. (4) Sperm cells. (5) Ciliated epithelium. (6) Sensory epithelium from retina of eye. (7) Flagellated (collared) epithelium. (8) A stinging cell from a hydra. (9) A glandular cell. (10) Connective tissue cells. (11) Fat cells. (12) A bone cell. (13) Smooth muscle cell. (14) A ganglion (nerve cell) with branches. (*Atwood and Heiss.*)

26. These different types of cells vary greatly in appearance, size, and shape in order that they may be adapted for the particular kind of work they need to do. But a few things are common to all cells. Each one is composed of **protoplasm** (*pro'-to-plazm*), the only substance in the world that is capable of sustaining life. When pure, this substance is jelly-like in consistency, grayish-white in color, and full of tiny bubble-like granules and clear

spaces, or vacuoles (*vak'-u-ōlz*). Seldom do we see pure protoplasm, however, because it can carry out its many functions only when other substances have been added which make it better adapted for its work.

27. A cell is composed of three principal parts. In the center there is a **nucleus** (*nu'-kle-us*) which seems to have great influence on the way the cell carries on its work and without which the cell cannot live. Surrounding the nucleus there is a portion of the protoplasm known as **cytoplasm** (*sī'-to-plazm*), and surrounding the nucleus and cytoplasm there usually is a **cell wall** or **cell membrane.** Later, we shall study some interesting animals whose whole body is made up of one cell, in some cases the cell membrane being entirely lacking. If you will look at the pictures of cells on page 19, you will note several different kinds. There are many other kinds besides those pictured here, the differences being due to the different kinds of work they do. For example, an epidermal cell covers a portion of the outside of a plant or animal and protects it. A muscle cell is adapted for contracting and, with many other similar cells, bringing about some kind of movement.

28. Growth.—Cells never grow to be very large. A few single-celled plants and animals and occasionally certain of the cells of larger ones may be seen with the unaided eye, but as a rule some degree of magnification must be used. Consequently, when a plant or animal is to grow larger than these structures, some plan must be used other than the increase in size of the single cell from which each individual develops.

29. In most plants and animals the first cell of the new individual results from the union of the nuclei of two parent structures. This fertilized egg cell, which is a single cell, soon divides into two cells. After a time a second division plane forms at right angles to the first, resulting in four cells. The process continues with the number of cells multiplied by two in each of these early divisions; that is, eight, sixteen, thirty-two, sixty-four, and so on.

30. At about the sixty-four-cell stage a change takes place in the ball of cells which is being formed. Those in the center move

toward the outside until there is a hollow sphere with a wall of cells which is one cell thick. This is known as the **blastula** (*blas'tu-lah*) stage of a plant's or animal's existence. After a short time a depression forms on one side of the sphere, which

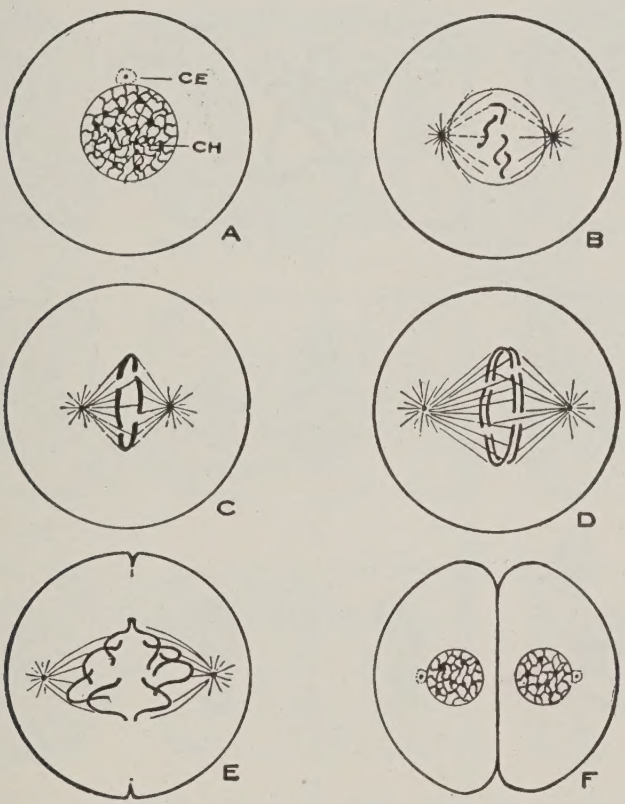


FIG. 13.—The division of an animal cell by mitosis. *CE* is the centrosome. *CH* is the chromatin. The centrosome splits into two and each one moves until they are on opposite sides of the nucleus. The chromatin forms definite bodies known as chromosomes. The chromosomes split lengthwise and tiny fibers connecting them to the centrosomes cause them to move toward the centrosomes. The chromosomes now clustered around the centrosomes break up into chromatin; nuclear walls appear; the cytoplasm divides. There are now two cells where there was one. (*Atwood and Heiss.*)

develops until the wall of the depressed part nearly touches the wall of the other part. This is the **gastrula** (*gas'-troo-lah*). The blastula may be compared to a rubber ball; the gastrula, then, may be represented by pushing in one side until a cup is formed. From this structure, by continued cell division, the **embryo,** or young plant or animal, develops. (See Figs. 157–160.)

31. Cell Division.—Cells reproduce in two ways. The simplest process is known as **amitosis** (*am-it-o′-sis*), fission, or simple cell division. The nucleus of the cell divides first. This division is followed by a pinching in two of the cytoplasm, which completes the process. This amitotic method of cell reproduc-

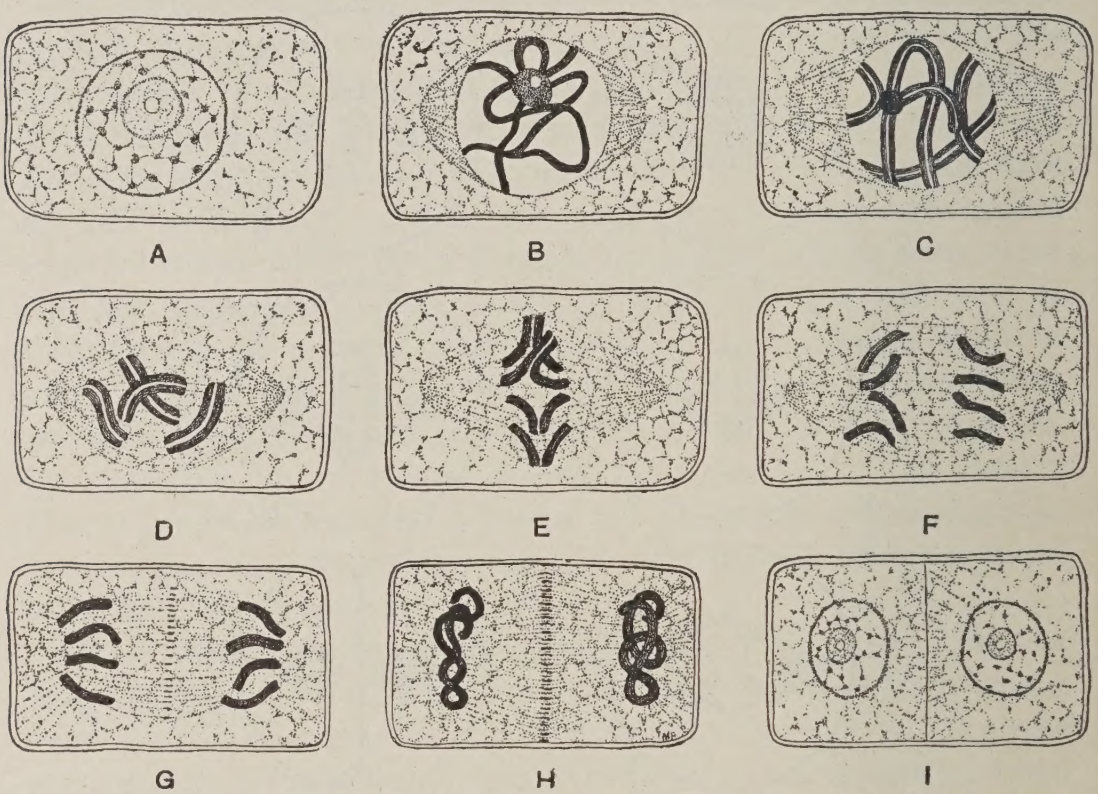


Fig. 14.—The division of a plant cell by mitosis. The process is similar in plants and animals, but in plants there is no centrosome. (*Atwood and Heiss.*)

tion is more common among the lower forms. Among higher types of plants and animals, a process known as **mitosis** (*mit-o′-sis*) is the usual method for producing two new cells. Before the actual division takes place, there is a careful distribution of tiny structures within the nucleus known as **chromosomes** (*kro′mo-somz*) which are believed to be the bearers of all the hereditary characteristics of the plant or animal. These chromosomes gather first as a tangled thread. The thread then breaks up into individual chromosomes which congregate along the center of the

nucleus. After dividing lengthwise so that each new cell will have the same characteristics, these heredity-bearing structures are pulled toward the ends of the cells, and a division of the cytoplasm takes place. There are now two cells, each having the

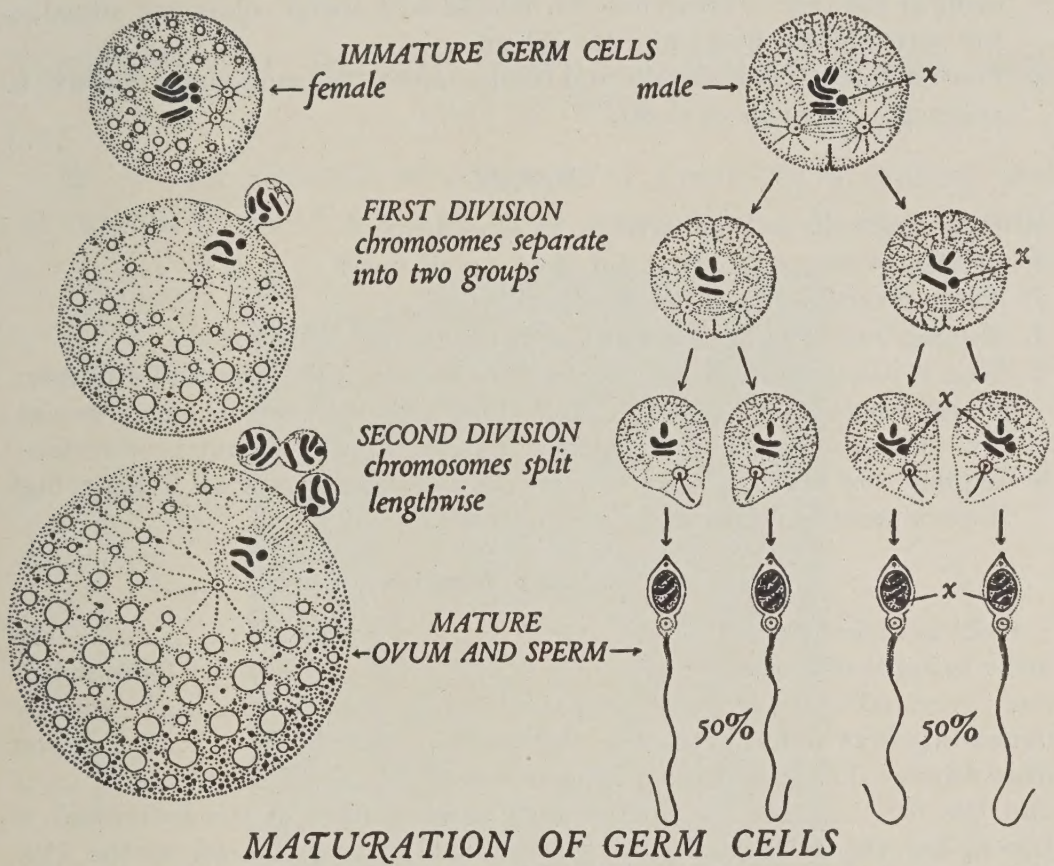


FIG. 15.—The mature sex cell differs from the immature sex cell in that it has half as many chromosomes. The x-chromosome determines sex, its presence causing the animal to be a female (in most species) and its absence causing the animal to be a male. In fertilization the chromosomes of the egg cell and the sperm cell are within the nucleus of the fertilized egg cell; thus the fertilized egg cell has the same number of chromosomes as the cells from which the egg and sperm cells came. (*Atwood and Heiss after Patten.*)

same number of chromosomes in the nucleus as the parent cell had in its nucleus.

When we realize that the process of cell division must be carried on again and again all through the life of the plant or animal, not only for growth but for the replacement of parts,

we get an inkling of the complexity and accuracy of adjustment necessary in these wonderful living houses we occupy.

Interesting Projects

1. With modeling clay, make models of the various stages in the development of the frog. These may be colored with water colors and added to the permanent collection of the school.
2. Place different kinds of cells and tissues under the compound microscope, and make drawings of them.

Review

1. How may cells be compared to building bricks?
2. Instead of true cells, what did Hooke really see?
3. Name several different kinds of cells.
4. Explain how growth of a many-celled organism takes place.
5. Why is it impossible for a single cell to become very large and still carry on its functions efficiently? Remember that as a cell increases in size, the volume increases more rapidly than the area of its nutritive surface.
6. Explain how the similarity of early development among all living things shows a general relationship among them.

Self-testing Exercise

Cells were first named by (1) _____ in the year (2) _____. In order to study cells effectively, a (3) _____ must be used. This instrument received much of its early development from (4) _____ who by nationality was (5) _____. Each cell is made of (6) _____, and nearly always has three principal parts, the (7) _____, (8) _____, and the (9) _____. In the early development of the individual, a two-walled cup is formed from the blastula; this is known as the (10) _____.

Define

amitosis
blastula
cell
cell division
cell membrane
cell wall
chromosome
cytoplasm
egg cell
embryo
gastrula
granule
lens
mitosis
nucleus
ovule
protoplasm
tissue
vacuole

CHAPTER VI

PROTOPLASM IS THE BASIC SUBSTANCE OF ALL ORGANISMS

32. We can separate certain parts of a plant or an animal, just as we can those of a clock or an automobile. If we are suffi-

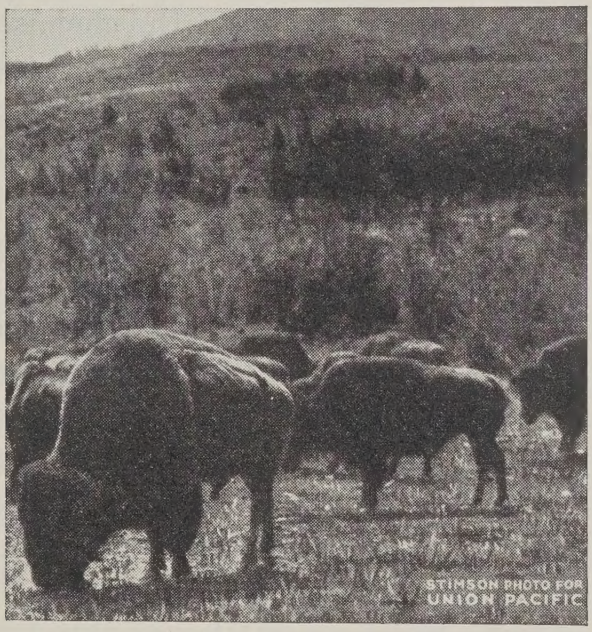


FIG. 16.—Both the bison and its food consist of protoplasm. (*Courtesy of Union Pacific Railroad.*)

ciently skillful we can put the clock or automobile together again and it will run. Not so the plant or animal, however. Its most important characteristic, life, has disappeared. No one has been able to give a wholly satisfactory scientific definition of the factor we call life and no one has ever been able to replace it after it has disappeared. You should remember this when you are hunting or fishing and are tempted to kill needlessly and in excess.

33. How the Plant or Animal is Made.—The whole plant or animal is often called an **organism** and the parts, **organs.** If we separate the parts of an organ such as the heart or the kidney of an animal, or the leaf of a plant, these parts are known as **tissues.** And the tissues in turn are composed of cells. So we can define a tissue, such as skin tissue or muscle tissue or the epidermal tissue on the outside of a leaf, as a group of similar cells performing a definite function. An organ, then, is a group of similar tissues which together perform a definite work, as the stomach of an animal carries on a part of the digestive process.

34. Compounds and Elements.—But the chemist would not be content to stop with the cell. He would want to know whether it would be possible to reduce protoplasm further by using heat, acids, solvents, or other agents. When he had arrived at substances which could not be subdivided further by any agency known to man, he would call them *elements.* Good examples of elements are some of the familiar metals—iron, copper, gold and silver. Certain of the gases, such as the nitrogen and oxygen of the atmosphere are less familiar but very common elements.

35. This work of chemists has been going on for ages. The Greeks thought there were but four elements; earth, air, fire, and water. It is now known that there are over ninety and none of the "elements" of the Greeks is on the list. Air is known to contain chiefly nitrogen and oxygen; water is composed of hydrogen and oxygen; while the earth contains all the elements. Fire is just the visible evidence of chemical union, usually of oxygen with other substances.

36. When a plant or animal grows, the substances which make growth possible come from the surroundings which are composed of elements. Therefore the elements which make up living, that is, **organic** material, may be found readily in non-living, *i.e.*, **inorganic** material.

37. It has been determined that protoplasm must contain carbon, hydrogen, oxygen, and nitrogen. Sulphur is usually present, too. The key word "CHONS" will help you remember

these, each letter of the word being the first letter of one of the elements.

38. We speak of the color, odor, degree of hardness, and other characteristics of any element as being its properties. Let us see what the properties are of the most important of the elements in protoplasm.

39. *Carbon.*—Coal is a familiar and quite pure form of this element. Its most common appearance is that of a black solid. As it is used in the furnace at home, it combines with another important element, oxygen, to furnish heat. At home, when the potatoes or cake have been allowed to burn, the heat has driven away most of the other elements, leaving principally the carbon.

40. *Hydrogen.*—This element is the lightest in weight of all the elements. It is a colorless, odorless, and tasteless gas. Because of its lightness it is sometimes used as a buoyant gas in balloons and dirigibles. It burns readily and is, therefore, somewhat dangerous for this purpose.

41. *Oxygen.*—This is the most abundant element. In combination with other elements it makes up a large part of the earth's crust besides composing one-fifth of the atmosphere, when measured by volume, and one third, also by volume, of water. We shall notice its importance again and again in our study of plants and animals. We know from its presence in the air that it is colorless, odorless, and tasteless. If you lowered a splinter of glowing wood into a bottle of oxygen, it would burst into flame, burning rapidly until the oxygen or wood was burned up. This shows that oxygen combines readily with other substances. It will not burn by itself, however. It only supports combustion.

42. *Nitrogen.*—This element makes up nearly four-fifths of the atmosphere besides being present with other elements in the earth. It, too, has no odor, taste, or color. It does not combine readily with other elements; consequently we shall find that plants sometimes have a difficult time getting enough for their needs.

43. We have mentioned that water is composed of hydrogen and oxygen. After learning the characteristics of these elements we see at once that water differs from both of them. When two or more elements combine in a definite proportion and lose their chemical properties, we call the new substance which has definite properties of its own, a **compound.** Not only water but most foods are compounds, as is protoplasm itself. If each of the elements retains its properties and the proportion is not always constant, then we have a **mixture.** Air is perhaps our most common example.

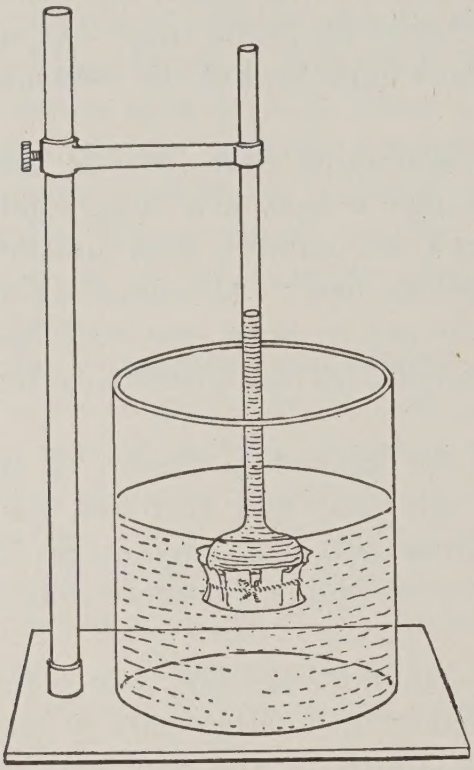


FIG. 17.—Apparatus to show osmosis through a membrane. The denser solution (grape sugar), within the thistle tube, represents the protoplasm within a cell; the less dense solution (water) represents the material around a cell. The membrane represents any cell membrane. Since the solution *rises* in the thistle tube, it is evident that there is a passage of water *inward* through the membrane, causing the column of liquid in the tube to rise. By testing the water in the jar for grape sugar (See Sect. 60), we find that a *smaller* amount of the solution had passed *outward* through the membrane into the water than had passed inward. (*Atwood and Heiss.*)

44. Osmosis (*oz-mo'-sis*).—We have thus far spent some time in the study of chemistry as it applies to biology. We now have to discuss a very important principle in the field of physics. This is the principle of **osmosis.** We have learned that protoplasm is thicker or more dense than water. We have also seen that protoplasm is done up in very small packages, the cells, each of which is usually surrounded completely by a cell membrane. It is necessary for food to get inside this membrane in order for the cell to live and develop, and it is necessary for the wastes resulting from the different processes to pass out through the cell membrane. The roots of plants are sur-

rounded by a soil water less dense than the protoplasm within the cells. Also, solutions of foods within the digestive tubes of animals are less dense than the surrounding protoplasm. There is usually a flow in both directions with the greater flow being toward the more dense substance. Follow through the description of the diagram on page 28 which represents an imitation of certain parts of plants or animals with their surroundings.

45. This experiment shows that the water passes through the membrane more rapidly than does the dissolved sugar. In nature, soluble minerals such as those found in soil water, diffuse through the membrane of a cell much as the dissolved sugar does in our experiment.

46. Whenever a membrane tends to prevent the diffusion of a **solute** (*sol′ūt*), such as dissolved sugar, but at the same time permits a **solvent** (*sōl′vent*), such as water, to pass through freely, it is known as a **semi-permeable** (*sem′-e-per′-me-a-bl*) **membrane.** A perfect semi-permeable membrane would allow only the diffusion of the solvent. Probably, however, there is no perfect semi-permeable membrane in nature.

47. The more rapid passage of the solvent produces an **osmotic pressure** which resulted, in our experiment, in causing the mixture of sugar and water to rise in the tube. In plants it contributes to the process of transferring dissolved substances up through the stem. The diffusion of water into the plant cell by osmosis also results in making the cell more rigid or firm, a condition known as **turgor** (*tur′-gor*). When plants lack sufficient water, this turgor is lost and the plant wilts.

48. As conditions vary in the structure of the protoplasm which lines the cell wall of a plant or forms the outside membrane of an animal cell, so does the kind of osmotic action vary. Certain solutes are permitted to pass at one time but not at another. A selection of materials often results which largely determines the kind of material characteristic of the plant. For example, a bean seed contains much stored protein in its cotyledons, but the corn fruit has an abundance of starch or sugar stored in the endosperm. This process of **selective osmosis** among cells

makes possible the adaptation of tissues for various functions such as the transfer of gases at one place while dissolved solids are diffusing in one way or another among other tissues.

49. Solids, Liquids, and Gases.—Changes in certain of the properties of the substances which make up this world of ours is another portion of physics of interest to the biologist. Most organic and inorganic substances can be classed as solids, liquids, or gases. A solid maintains a constant shape and size. A liquid conforms in shape to the vessel which contains it, but its size remains the same. A gas differs from solids and liquids

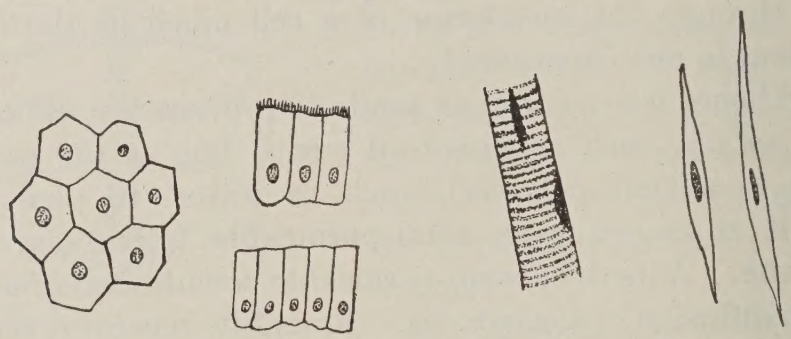


FIG. 18.—Different kinds of cells and tissues. (*Holmes.*)

by changing both its shape and its size to conform to the limits of the vessel which holds it.

50. A substance may be changed from one class to another by a change in the physical conditions surrounding it. For example, we have often seen the effect of change of temperature on water, a liquid. At temperatures below 32°F. it freezes into a solid, and at temperatures above 212°F. it becomes water vapor.

51. When the former conditions return, the substance likewise returns to its original state. That is, when the temperature rises above 32°F., ice melts to become water. When heated, water vaporizes, and when this vapor is expelled into the cooler outside air it condenses into steam, which is made up of tiny droplets of water.

52. These changes are physical. When a chemical change takes place, the former properties cannot be restored so readily. For example, when a stick of wood burns, cooling it by pouring on water does not restore the burned portions.

53. There are organic as well as inorganic solids, liquids, and gases. Bones and teeth of animals, crystals of materials in plants are solids derived from organic substances. The watery portions of the blood of animals and the sap of plants are liquids, and the carbon dioxide given off from both plants and animals in respiration is a common gas.

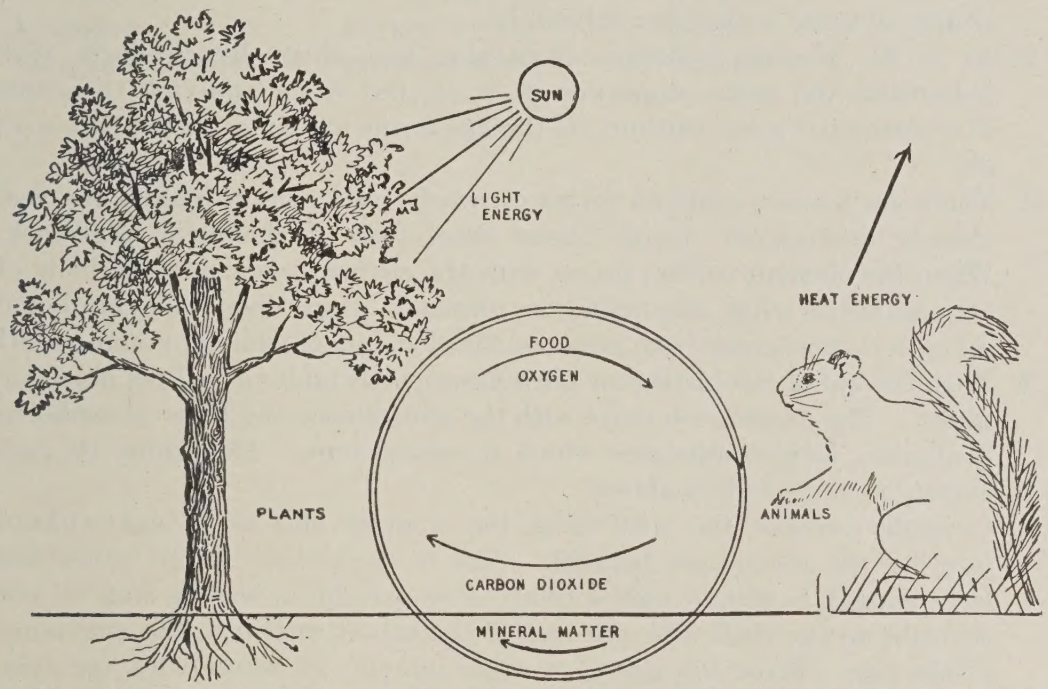


FIG. 19.—The squirrel eats the plant substance such as the acorns of an oak tree; on the other hand the waste products of the squirrel in the air and soil are useful to the plant. (*Atwood and Heiss.*)

54. Protoplasm, when pure, is a semi-fluid; that is, it is neither solid nor liquid. But because of the varied tasks the different parts of plants and animals must do, it assumes many forms, or produces substances which may be in any one of the three classes.

55. We shall note many times, during our study of biology, the ability of protoplasm to perform complex processes. The greater the ability of the parts of a plant or animal to become adapted to the needs of the organism, the more successful the organism as a whole will be. The relationships of organisms

to each other and to their surroundings form an important part of the study of biology.

Interesting Projects

1. With the aid of the instructor, prepare oxygen from potassium chlorate and manganese dioxide. Determine the following properties of the gas: color, odor, taste, weight as compared with air, solubility in water, and ability to unite with other substances.
2. As in #1, prepare hydrogen from zinc and dilute hydrochloric acid. Determine the same properties as in #1, but when applying the flame of a match use great caution, as the gas forms an explosive mixture with air.
3. There are several common forms of nearly pure carbon besides the coal already mentioned. Learn about these from a chemistry text-book. When the element carbon unites with the element oxygen in the body of an organism, what compound is formed? How does this compound differ in its properties from either of the elements of which it is composed?
4. With the aid of the instructor burn phosphorus under a bell jar placed in water. The oxygen will unite with the phosphorus and form phosphorus pentoxide, leaving nitrogen which is nearly pure. Determine its properties as in #1 and #2 above.
5. Carefully remove the shell from the rounder end of an egg without injuring the membrane beneath. Cut a round hole in the other end large enough to admit a glass tube. Use paraffin or sealing wax to seal the tube to the shell with one end of the tube thrust into the substance of the egg. Place the egg in a small amount of water with the tube supported in an upright position. Account for the change in the level of the liquid in the tube.

Review

1. How would you distinguish between organism and organ; tissue and cell?
2. What are the differences between elements and compounds; between compounds and mixtures?
3. How do changes in temperature usually affect the properties of substances?
4. What is the importance of selective osmosis?
5. How does osmotic pressure assist the rise of sap in the stems of plants?
6. Why can there be no elements in the body of a plant or an animal that are not found in the earth?
7. If it suddenly became impossible for osmosis to take place anywhere in the world, how would plants and animals be affected?

Define

acid
carbon
carbon dioxide
compound
diffusion
element
endoplasm
hydrogen
inorganic material
mixture
nitrogen
organ
organic material
organism
osmosis
osmotic pressure
oxygen
physical change
protein
respiration
selective osmosis
semi-permeable membrane
soluble minerals
solute
solvent
turgor
volume

CHAPTER VII

EVERY LIVING THING CARRIES ON THE SAME LIFE PROCESSES

56. The football coach constantly appeals for teamwork. He knows that the individuals must work together to accomplish an effective result; that the failure of any one player may make futile the efforts of the others.

And so it is with both the parts and the functions of the body of the plant or animal. Each is so dependent on all the others and the whole is so dependent on each part and each function that the failure of any one part often results in disaster. We have already considered the relationships among cells, tissues, and organs, but what are the processes or functions which are so essential?

57. Irritability.—First there is irritability. One of the most noticeable characteristics of protoplasm is its ability to respond to stimuli—such as heat, light, electricity, and certain chemical compounds. Leaves of plants turn toward the light. This is especially noticeable when plants are placed in a window where the light comes from only one direction. The odor of food is a chemical stimulus which causes animals to go to that source. Even you and I are influenced by the delectable odors of favorite foods. On the other hand, we know that sunlight or odors would not have any such effect on mineral material, such as stone or a metal.

Only extreme changes affect inorganic material; in many cases, however, organic things cannot even live unless the temperature is above the freezing point or below the boiling point of water.

Protoplasm is often adapted in a remarkable way to receive certain kinds of stimuli. For example, there are the nerve endings in the eye which pick up light stimuli; nerve endings in the ear which respond to sound stimuli; specialized nerve endings in the skin which give us the sense of touch.

FIG. 20.—The flower of the Night-blooming Cereus (a species of cactus) is adapted to show its beauty only at night. The flower usually opens late in the evening, and by daylight the following morning, it has withered. Bright colors are not needed by night-blooming species, and we find them invariably to be white. (*Courtesy Fallot Studio.*)

58. Contractility.—When an animal becomes aware of food or danger or of uncomfortable surroundings, the ability to move permits a change of location. The possibility of motion, resulting from the contraction of protoplasm in organic substance is derived from within itself; inorganic substance, however, must be moved by some force without itself. That is, a dog moves along

under its own power, but a stone must be moved by wind, water, or some other external force. Have you seen a sensitive plant which quickly closes its leaves when touched? If so, you have seen a dramatic example of the possibility of contractility in plants. Morning glories close up at night; sunflowers turn with the sun as it crosses the sky; the Venus fly-trap quickly closes

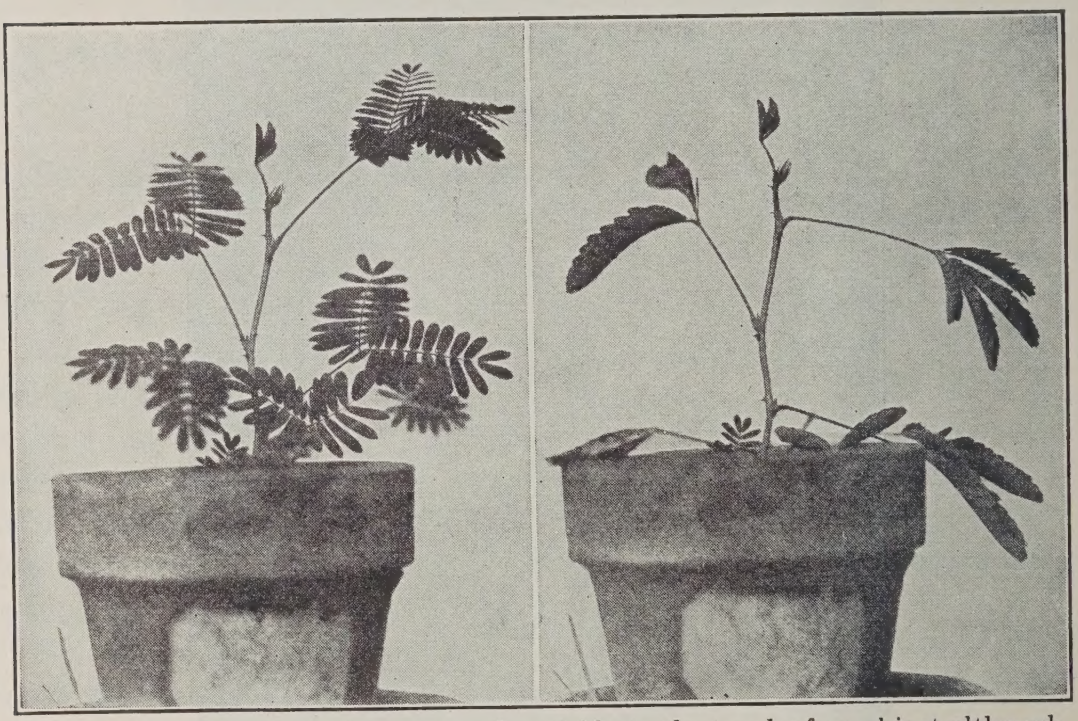


FIG. 21.—The sensitive plant responds quickly to the touch of an object although it has no nervous system. (*Atwood.*)

its leaves to capture an insect which touches it. Yes, plants are able to move even if they do not walk around.

59. Nutrition.—When plants and animals move, protoplasm breaks down and the energy which is used must be replaced. This is accomplished by the process of **nutrition.** Most foods taken into the animal body or built up in the plant body are not suitable to become a part of the body at once. Some of the cells are adapted for combining certain substances in such a way that the new compounds may be used in changing the nutrients. These substances, formed only by protoplasm, are known as

secretions. The action of secretions on nutrients is called **digestion.** The process of digestion results in both physical changes (changes in form) and chemical changes (changes in composition) so that wastes are separated from the nutrients

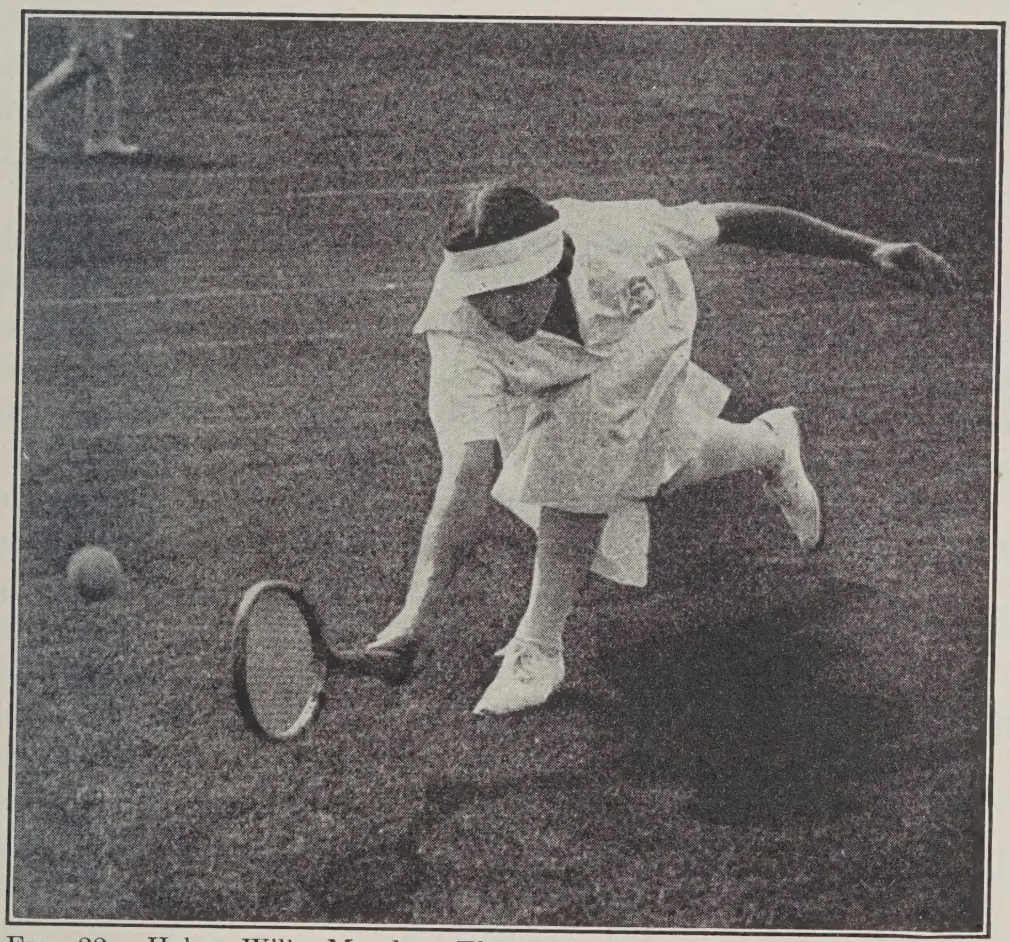


FIG. 22.—Helen Wills Moody. The activities of an athelete show that much "teamwork" among the different parts of the body is necessary. (*Keystone View Co., Inc.*)

and these nutrients are usually transferred through membranes by the process of **absorption.** The nutrients are then moved to the many tissues and cells where they are to be used. In most animals there is a fluid known as blood which is caused to circulate throughout the body, sometimes by a heart, as in the higher forms, and sometimes by muscular action, as in certain of the

lower forms. This same fluid, blood, serves to carry some products to the cells and other products away from them. Among the plants, however, there are two systems, separate from each other. One system takes materials from the roots up through the stem to the leaves, there to be made into food. The other system takes the food from the leaves and distributes it among the many parts of the plant where it is either used or stored for some future need. Finally, by complex changes the nutrients become parts of living cells. This last process is known as **assimilation.**

60. Nutrients are both organic and inorganic. Organic nutrients are substances formed by protoplasm, such as milk and fruit juices, or portions of the protoplasm itself, as represented by meat and vegetables. Inorganic nutrients are those not derived directly from protoplasm, such as minerals and water.

The organic nutrients may be arranged in three groups, the carbohydrates, the proteins, and the fats or oils. Carbohydrates,

Nutrient	Procedure	Result
Starch (a carbohydrate)	Add a small amount of dilute iodine solution to starch which has been boiled in water	Starch becomes dark purple
Grape sugar (a carbohydrate)	Add Fehling's solution to the grape sugar in solution and heat	A reddish-brown precipitate forms
Protein	Add nitric acid slowly and cautiously to the heated protein in water; after a yellow color appears add ammonium hydroxide	Protein becomes bright yellow in nitric acid; when the ammonium hydroxide is added the yellow color becomes darker
Fats and oils	Rub the mashed food containing fat or oil on a piece of unglazed paper	Heat slowly; water evaporates but spots of oil remain

(starches and sugars) contain three elements, carbon, hydrogen, and oxygen. The hydrogen and oxygen are present in the same proportion as in water. Proteins (meat, fish, eggs, and cheese) contain nitrogen in addition to the carbon, hydrogen and oxygen. Fats and oils contain carbon, hydrogen and oxygen, but in a different proportion from that found in carbohydrate food.

The presence of these nutrients in any food may be detected by applying the tests as given at the bottom of page 38.

61. Reproduction.—After carrying on these processes for a time, the organic mechanism which we call a plant or an animal wears out if it has not already been destroyed by an enemy or by an accident. As this change which we call death finally comes to all plants and animals, it is evident that life would soon cease to exist if there were not some way to produce new forms. By the process of **reproduction** the continuance of each species is assured.

This function, unlike the others, is not necessary for the continuance of life in the individual, but it is absolutely necessary if each kind or species of plant or animal is to continue to inhabit the earth.

62. Spontaneous Generation.—Many years ago it was generally believed that certain forms of life arose spontaneously; that is, that they were created out of certain substances not living at the time. For example, people had noticed that decaying food soon became infested with many different kinds of life, both plant and animal. It was supposed that these were formed from the elements released from the decaying substances.

63. An Italian scientist, Redi (*Ra-de*), by means of a clever experiment which was repeated later by Pasteur, the French scientist, proved that this belief was erroneous. He placed food in three jars. One jar was left open, the second was covered by a cloth which would allow some exchange of odor-laden air, and the third was completely sealed. As he suspected, the material in the first jar was soon covered with the larval forms of flies and certain of the plants known as fungi, many of which thrive on

decaying material. The eggs of insects and the spores, or reproductive bodies of fungi, were found on the cloth of the second jar but no life was visible inside. The material in the sealed jar remained without change.

This experiment, with others similar in principle, resulted in the belief that life is not now being created; that all plants and animals living today have come from other plants and animals by the process of reproduction.

64. Growth.—The reproduction of cells brings about growth. Sometimes these new cells are used to replace others which have

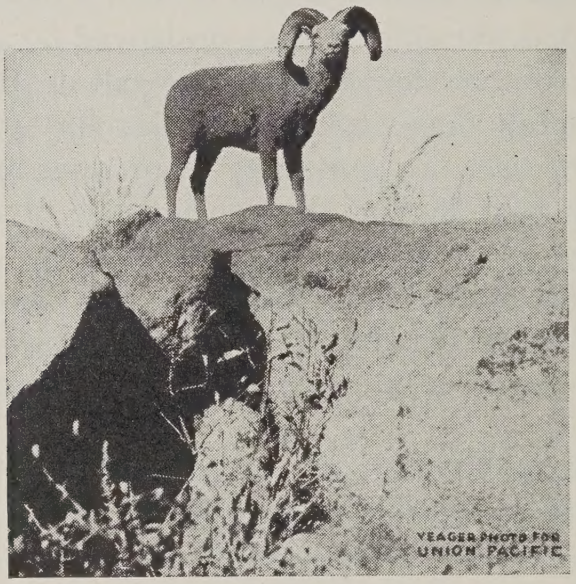


FIG. 23.—The Rocky Mountain bighorn sheep responds to many factors in its environment. (*Courtesy of Union Pacific Railroad.*)

become worn out; at other times new cells are formed to replace the ones destroyed by injury as when a cut fills in or heals. Then there are the ordinary increases in size with which we are familiar.

Growth is usually intermittent, that is, there are periods of rapid growth followed by intervals during which growth may be so small in amount that it is not perceptible. Trees grow more rapidly during the warmer seasons. Boys and girls increase their size more during some years than others.

Stones may occasionally increase in size if conditions necessary for the addition and solidifying of new material are present. Icicles may likewise become larger if additional water freezes to the outside. It is evident, however, that this increase in size of inorganic objects is fundamentally different from the growth of organisms.

65. Respiration.—In order to change the material found in the cell in such a way that energy can be liberated, oxygen must have access to it. In the higher animals this is taken in by lungs, in fishes and some of the lower forms by gills, and in many plants through tiny openings in the leaves known as stomata. We shall learn more about these structures later. When this oxygen gas combines with the food material within the cells, some of the carbon unites with oxygen forming carbon dioxide gas, energy being thus set free for the organism to use. When a cell takes in oxygen and gives out carbon dioxide, the process is known as **respiration.**

66. Excretion.—Whenever protoplasm or food or oxygen is used in the plant or animal body for the liberation of energy for motion or heat, or to assist in the production of some such product as a digestive fluid, waste products are usually formed. One of the most familiar of these is the gas, carbon dioxide, a compound of carbon and oxygen which develops from the union of oxygen with some substance containing carbon, such as food.

The air-breathing animals like ourselves get rid of this waste by means of the lungs. Many of the animals that live in the water, like the fishes, use their gills to dispose of it. The plants have openings in their leaves, which we have already mentioned, for releasing it; although as a matter of fact, very little is released because it is used in another process.

Waste products resulting from the breaking down of protoplasm are usually rich in nitrogen. Perhaps the most familiar of these waste substances among animals is urea.

Plants do not have specially designed organs like kidneys for getting rid of wastes. They use such ingenious devices as

storing their wastes among the cells of the leaves. Here the wastes remain until the leaves drop in the autumn, when, after the green coloring matter and stored food are removed to the stem and roots, they fall with the leaves. It is fortunate that the plants have this way of getting rid of their wastes, because these materials form the bright colors which we see only after the green material has been removed. What a drab season

FIG. 24.—Outdoor activities of all kinds require the energy produced by the oxidation of nourishing foods. (*Phila. Council, Boy Scouts of America.*)

autumn would be without the gay colors of the foliage, when every tree of the woods and parks is either a blaze of color or a part of the dark green background of evergreens! You will in the future, I am sure, associate these red and yellow colors of autumn with the process that forms them. It is excretion.

67. Metabolism.—The functions of protoplasm which make life possible are **cell** processes, that is, they make life possible within the cell. And the life of the organism as a whole is dependent on this fact.

A summary of these processes is as follows.

irritability
  contractility
nutrition
  digestion
    secretion
  absorption
  circulation
  assimilation
reproduction
growth
respiration
excretion

Sometimes all these processes involving cell activities are grouped together and called **metabolism.** This may be divided into the building-up processes, such as assimilation, growth and reproduction; while the breaking-down processes are represented by respiration, irritability and contractility.

68. The Periods of Life.—Although the periods of time that the many different kinds of plants and animals live vary widely, we find in practically every life a period of youth, a middle period of maturity, and a declining period of old age. In a tree like the Sequoia (see frontispiece), some of which are over four thousand years old, the period of youth would be long, possibly a thousand years. But certain of the insects require only one night for their entire adult life.

69. The Life Cycle.—We may speak of the total period of life, or **life cycle,** as it is usually known, in a biological sense or in a chemical sense. Biologically, most plants and animals start life as a single cell which has resulted from the union of two nuclei. At the time of maturity reproduction usually takes place, and new forms of the same kind of plant or animal start the development of their cycle. Each generation of the endless chain starts in the same way—from single cells, and the life of each individual is finally completed by the change known as death.

Chemically, we look at the matter from a slightly different angle. Here we are concerned with the elements which each

plant or animal has acquired in the formation and building processes of its body. Many of these elements are formed into compounds which are often broken down or built into other compounds. In these processes, as we have noted above under excretion, substances are thrown off which are of no further use to the individual at the time but which may be of value at a later time, or to other organisms. For example we have the fertilizers which are so commonly used, made of the wastes from animals; also we know that the deposits of decaying leaves in the forest are valuable in aiding the further development of other plants. At the same time, during the growth of the individual in size, some of the assimilated food material becomes a permanent addition. This remains until death. Then Nature makes a wise provision in causing it to decay so that the elements and compounds may be released for the use of other organisms. Otherwise the surface of the earth would soon become cluttered with the remains of millions of plants and animals. So here we have another kind of cycle; elements and compounds taken from the surrounding inorganic material, used, and then returned by excretion or by decay.

70. The Conservation of Matter.—It is believed that the amounts of the elements on the earth remain always the same. They undergo changes from time to time and are formed into different compounds, so there appears to be more of one element at one time than at some other time. For example, wood is made from many elements and compounds derived from soil water which entered through the roots, and gases from the air, combined with the aid of the leaves. When the wood is burned, gases and smoke are given off, along with heat and light. The ashes that remain often represent but a small part of the original total amount. However, if all the gases were saved and weighed with the ashes, the result would be surprising at first, because this group of substances would weigh more than the original wood. When we remember that burning is a process whereby oxygen is added to a substance, we then know that an element has been added; consequently the weight has

become greater. This fact that nothing is added to, or lost from, the total amount of material is known as the **Law of the Conservation of Matter.**

71. The Balanced Aquarium.—We shall learn of many relationships among plants and animals as we continue our adventure among the marvels of nature. Perhaps the most familiar example to most of us is furnished by the **balanced aquarium.**

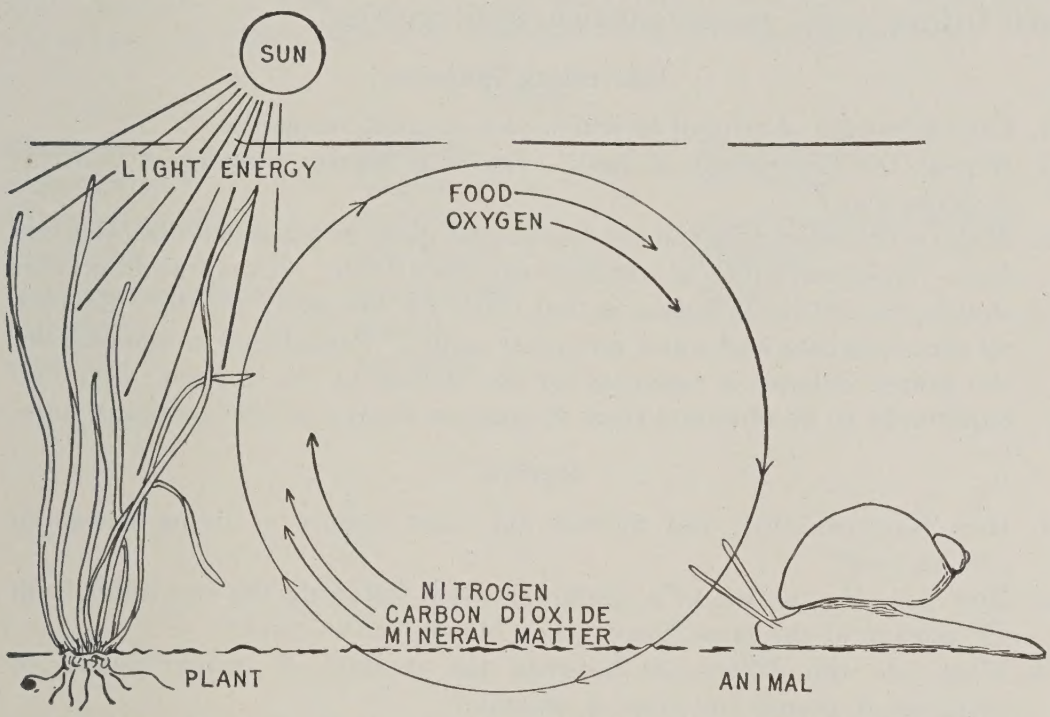


FIG. 25.—Diagram of a food cycle in an aquarium. (*Atwood and Heiss.*)

The ability to achieve this balance is based on the fact that animals give off carbon dioxide, a compound essential to plants for making their food, and, in this same process of food production, the plants give off more oxygen than they need for their own use. This gas which is essential for oxidation within the animal body, thus becomes available. In an aquarium this principle may be used by adding just enough plant life to balance the animal life, which may consist of goldfish, salamanders, turtles, snails, or other water animals. When the balance is once attained, the aquarium will need no further attention except to replace the water that has been lost by evaporation, and food to

supply the animal inhabitants.[1] If there is no plant life, then the water must be frequently changed to provide oxygen. Oftentimes loss of life results when the water is changed, because the change of temperature of the water added is too sudden. The balanced aquarium also avoids this possibility.

If you have an aquarium at home that is not balanced here is an opportunity to use your biological knowledge to save yourself future work, inconvenience, and expense.

Interesting Projects

1. Give examples of stimuli to which you yourself respond.
2. Repeat the experiment of Redi. Do your results correspond with his in every way?
3. Make a balanced aquarium in the largest glass or enameled dish you can find. Have one gallon of water for each small fish. If the water becomes cloudy, the probable reason is that there are too many plants. Remove all the organisms and water and start again. Persistence in determining the proper balance is essential for the success of this project. But the enjoyment to be obtained from its success repays all the necessary care.

Review

1. How do irritability and motion aid most species of living things in getting food?
2. How does the motion of a sunflower when following the sun differ from the motion of the same flower when blown by the wind?
3. What are the differences between the method of transportation of materials in plants and that of animals?
4. When Redi performed his experiment, why did he use three jars instead of just the sealed one?
5. If material placed on balances is ignited under a sealed bell jar, the weight does not change although the form of the material may be entirely destroyed. Explain.

Self-testing Exercise

The response of protoplasm to stimuli is known as (1) _____. The function of nutrition is composed of the four following processes, (2)

[1] Experiments have shown that the aquarium can be arranged so that neither water nor food needs to be added. Aquaria have been sealed for as long as two years. When sealed, the water cannot evaporate and the animal inhabitants depend on the plants for food. Then the plants must grow rapidly enough to keep ahead of the loss of substance.

_____, (3) _____, (4) _____ and (5) _____. When a cell takes in oxygen and gives out carbon dioxide, the process is known as (6) _____. New plants and animals are brought into existence by the life function (7) _____. The Italian scientist, Redi, proved that the theory of (8) _____ has no present scientific basis. All cell processes grouped together are known as (9) _____. These are divided into the building-up processes such as (10) _____, and the breaking-down processes such as (11) _____. The three periods of life are (12) _____, (13) _____, and (14) _____. The (15) _____ aquarium represents a portion of nature brought indoors.

Define

absorption
assimilation
balanced aquarium
circulation
conservation of matter
digestion
excretion
function
fungus
irritability
life cycle
metabolism
nutrient
nutrition
reproduction
soil water
spontaneous generation
stimulus
urea

CHAPTER VIII

LIVING ORGANISMS ARE RELATED TO FOSSILS

72. Man has long been interested in the many curious and strange plant and animal forms that have been dug out of the

FIG. 26.—Fossils being uncovered. A heap of Giant Sloth bones. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

ground. The old caves, where prehistoric man made his abode, have likewise, yielded their treasure after enthusiastic and persistent excavation and study. Some of the world's greatest scientists have unearthed remnants which furnish positive proof that long before the oldest civilization known, there lived plant

and animal forms about which we, hitherto, knew nothing. These remains have been carefully preserved and are now on display for us and future generations to view and study. Now, let us see where these skeletal fragments and fossils came from.

73. Most things pass away in a few centuries. Few of the trees, and none of the animals of today will be alive a thousand

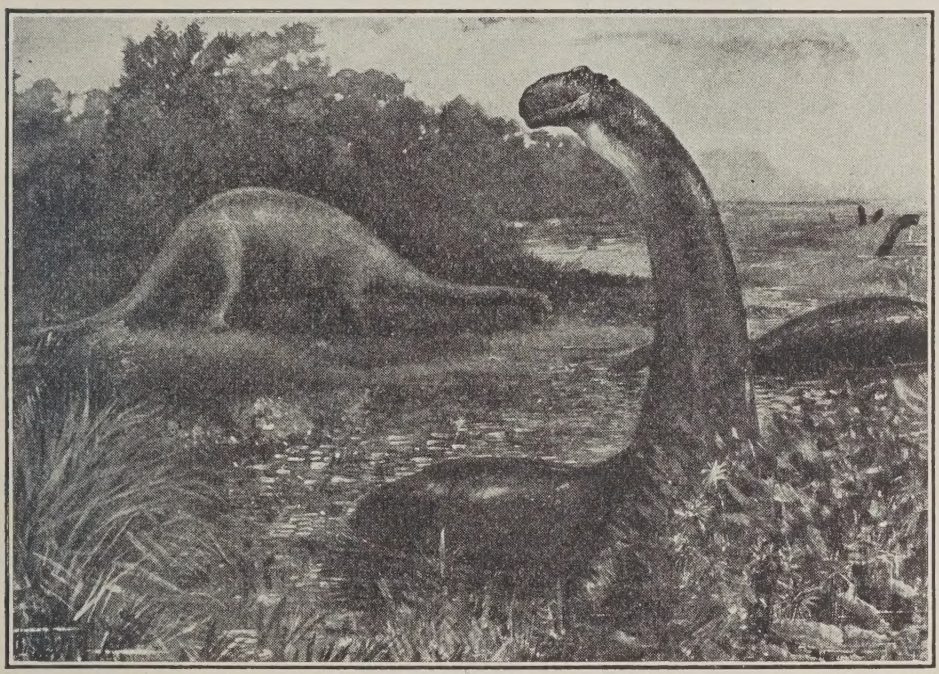


FIG. 27.—Reconstruction of a prehistoric swamp. (*American Museum of Natural History.*)

years from now. Most of their bones and remains will have decomposed and turned into dust. These processes have been going on just this way for unknown centuries. But, fortunately, there are places where these remains were covered over by mud or sand, and later were sealed up when this sediment turned into rock. Other animals became trapped in the great asphalt beds such as those in certain of our western states. Being thus protected from air, winds, rains, frosts, and underground waters, they were not disintegrated. Such remains, when found, disclosed the actual bones or other hard parts of the living things that inhabited the earth long, long before even man.

74. By means of such fossils, scientists have been able to trace the development of many kinds of living animals, such as the horse, down through the centuries from the time when it was little larger than a small dog and walked on four or five toes, until it became the animal that we know so well today. Many

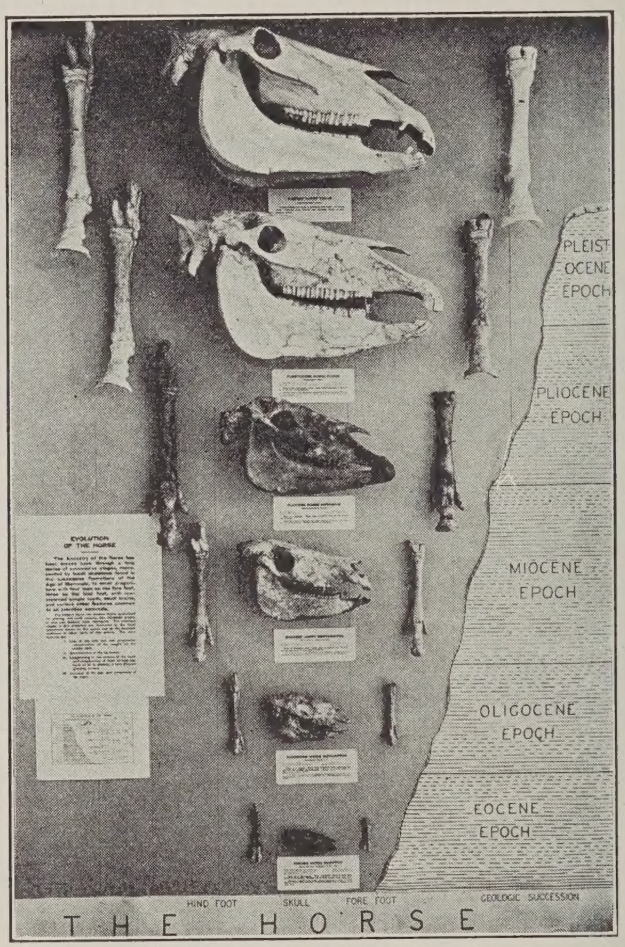


FIG. 28.—The horse has had a very interesting development since the time when it was a small animal, no larger than a dog. (*American Museum of Natural History.*)

other similar examples might be given. But how much more the development of any race or species will mean to you if, at your first opportunity, you visit any of the large natural history museums and see these fossil records for yourself!

75. A great many years ago some persons thought that fossils were the imperfect **models** of animal forms designed by the

Creator, but were not good enough to become the forerunners of races of living animals. We now know that, at one time, they **were** living races, which, for one reason or another, either perished or were gradually changed to slightly more complex forms.

There is so much similarity of structure between fossil forms and the organisms living today that there can be no doubt about their being related to each other, even though the two lived at widely different periods of time.

Interesting Projects

1. Collect and mount on sheets of cardboard, or copy pictures of plants and animals which are now extinct.
2. Visit any natural history museum if possible, and study the various fossil forms on display there. Compare them with their nearest living relatives and thus see for yourself how these fossil species are related to present-day forms.

Review

1. What are fossils?
2. How may fossils be preserved?
3. What do fossils show us about prehistoric life?
4. How does our present knowledge of fossils differ from the old ideas about them?

Define

asphalt beds
decompose
disintegrate
excavation
prehistoric man
sediment
skeletal fragments

UNIT III

EACH PART OF A PLANT IS ADAPTED TO CONTRIBUTE TO THE SUCCESS OF THE ORGANISM AS A WHOLE

CHAPTER IX

THE LEAF IS A FOOD FACTORY

76. Leaves are such commonplace things that we hardly think of them except when they make their welcome appearance in the

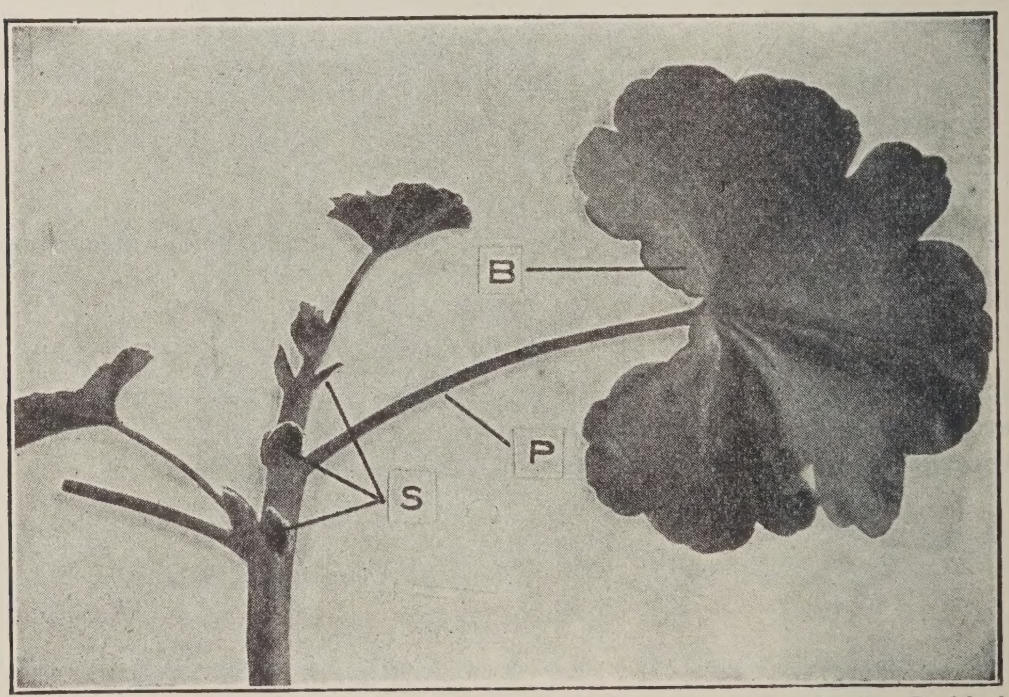


FIG. 29.—Parts of a typical leaf, represented by a geranium leaf. *B*, blade; *P*, petiole; *S*, stipules. (*Atwood and Heiss.*)

spring or when they add so much to the beauty of our hillsides with their bright colors in the autumn. As a matter of fact, they are of the greatest importance to all animals as well as to the

plants, because it is the green leaf which, by taking carbon dioxide from the air and water from the soil, and by using sunlight as a source of energy, is able to build carbohydrates. It is possible for the green leaf to do this because of the presence of the substance which gives the green color to the leaf, namely **chlorophyll** (*klo'-ro-fil*). As there is none of this material in animals, they

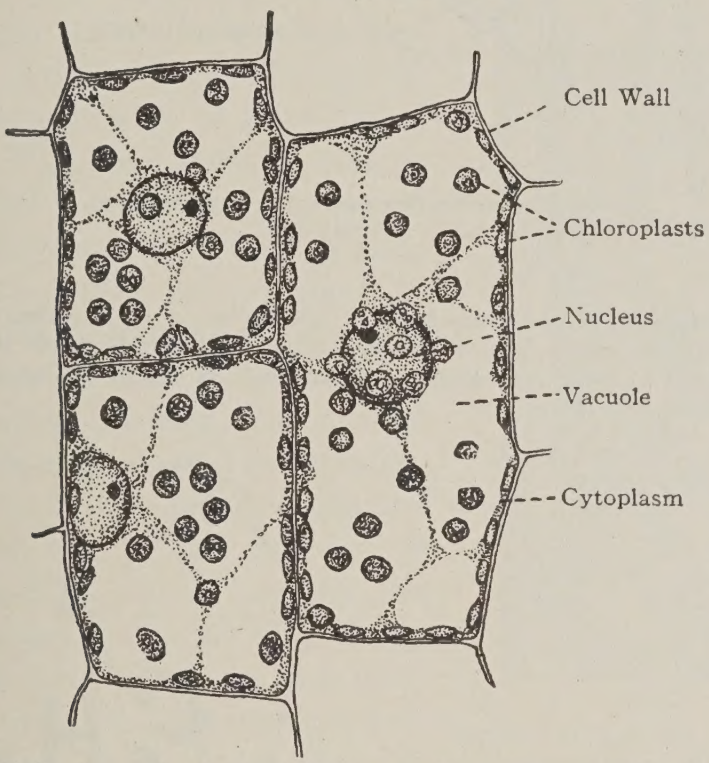


FIG. 30.—Cells from the leaf of Elodea. The chlorophyll is in tiny bodies called chloroplasts. Often, in the sunlight, these bodies circulate usually along the inside of the cell wall. (*Mottier.*)

must depend upon the plants. This is true even of the flesh-eating forms, such as the wolves, because the animals they prey upon must, in turn, prey upon plant-eating animals or else feed on plants themselves.

77. The green substance is usually present in tiny bodies called **chloroplasts** which are scattered throughout the cytoplasm of many of the cells. When we analyze the name of this process, **photosynthesis** (*fo-to-sin'-the-sis*), we find that it means 'putting together by means of light' (phos—light; syn—together; tithemi —place).

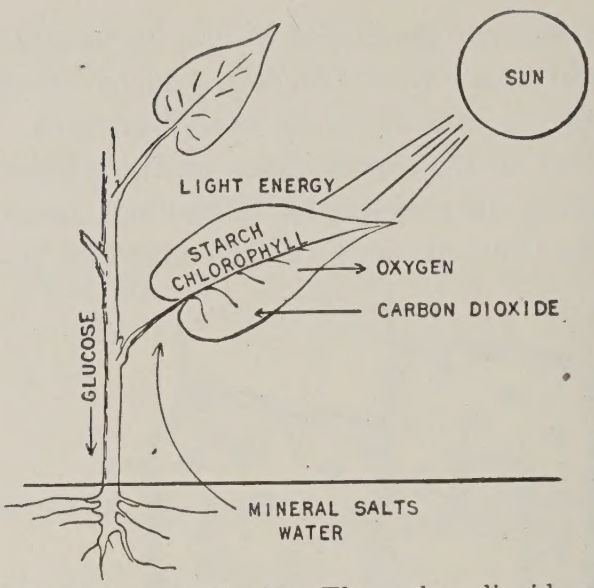


FIG. 31.—Diagram of photosynthesis. The carbon dioxide comes from the air where it is replenished as a waste from animals. Carbohydrate is made as a glucose, changed at once into starch, transported as a glucose, and stored as a starch. (*Atwood and Heiss.*)

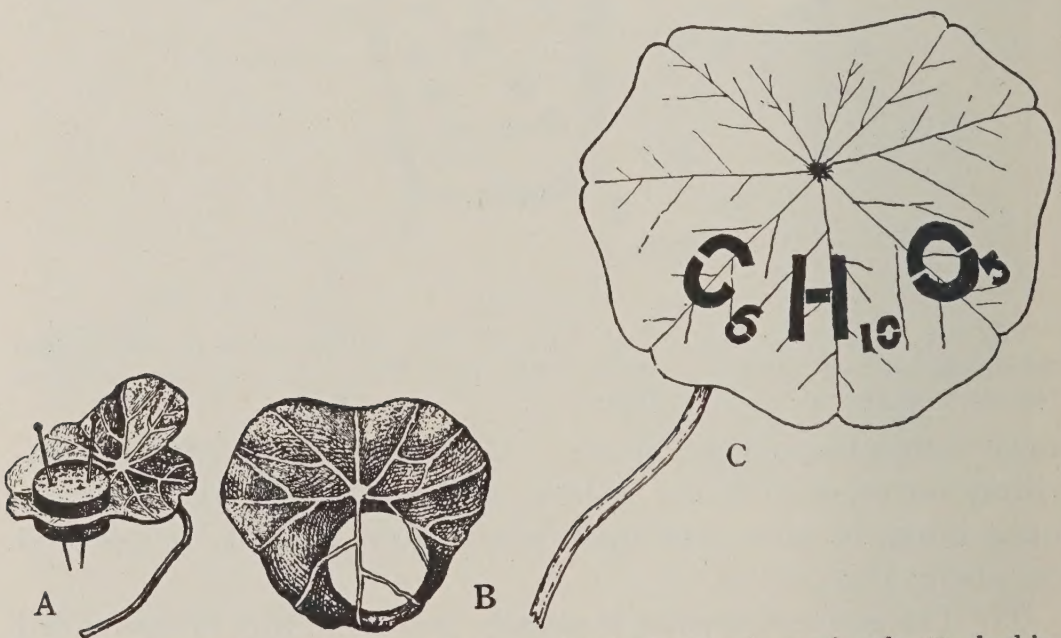


FIG. 32.—Starch formation in leaves. *A*, a leaf with pieces of cork attached in such a way that light is cut off. *B*, the same leaf twenty-four hours later, treated first with alcohol to remove the chlorophyll; then with iodine to show that starch was withdrawn from the shaded portion and no more was made. The chlorophyll area not shaded turned dark blue, showing the presence of starch. *C*, the same procedure was followed except that the entire leaf was shaded except the letters *CHO*. (*Mottier.*)

78. Food Substances Made in Leaves.—Sugars are formed first but are changed almost at once to starches. For this reason the process is commonly mentioned as a "starch-making process". Proteins are formed from carbohydrates by rearranging the carbon, hydrogen, and oxygen present and by adding nitrogen, phosphorus, and sulphur. Fats are formed by changing the arrangement or amounts of the parts of the elements in starch. It is evident that the process of photosynthesis must be accomplished first. Leaves cease their labors of carbohydrate production at sundown, resuming them at dawn.

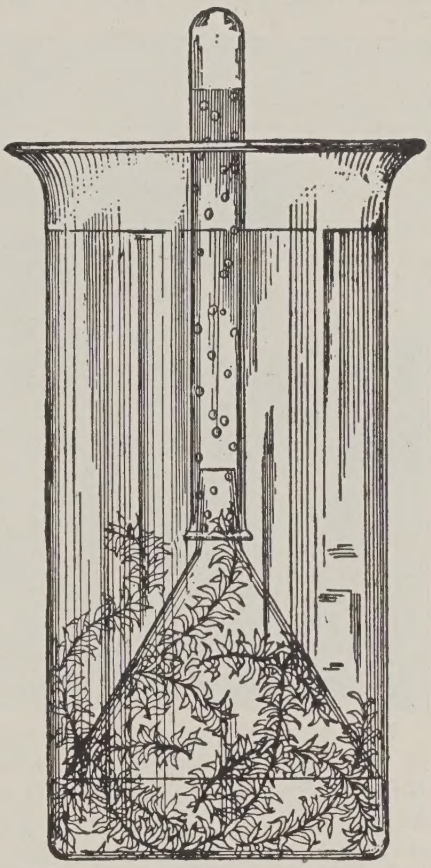


FIG. 33.—Apparatus for showing that oxygen is a by-product of photosynthesis. Place pieces of a water plant such as Elodea under an inverted funnel and keep in the sun for several hours. Bubbles of gas will be seen rising through the funnel. Place a test tube full of water over the end of the funnel and test the collected gas. A goldfish placed in the jar to supply carbon dioxide gas will cause better results to be obtained.

79. Besides making their own food, which may be used by animals, plants replace the oxygen which has been used up in the process of respiration by animals and by the plants themselves. As we have already noted, plants take in carbon dioxide which contains carbon and oxygen. The water from the soil contains hydrogen and oxygen. That is, there are two sources of oxygen, and when the carbohydrates are formed of carbon, hydrogen, and oxygen, some of the oxygen is left over. We have already learned why it is necessary for both plants and animals to have oxygen supplied to the cells. So part of this excess oxygen is used in the plants' own process of respiration, but not all is needed. Therefore we find that the plants and animals are mutually

helpful in their exchange of gases. The animals take in oxygen and give out carbon dioxide which the plants need and use. But in doing so, oxygen is produced by the plant so abundantly that part of it is available for the animals.

FIG. 34.—Photosynthesis is carried on in the branching stems of the cactus. Here a Papago Indian, near Torreo, Mexico, has obtained water from the storage spaces in the cactus stem. (*From Gager after Coville and MacDougal.*)

80. After the food substances are made, they must be changed by a process of digestion so that they may be absorbed by the cells. Not all of the material is to be used by the cells of the leaves and part must be stored for use when there are no leaves or when there is no light for photosynthesis. Storage is usually either in special cells of the stem or in the root, but food may be stored in almost any part of the plant, in the fruit or the seeds.

81. Leafless Plants.—Some green plants, such as the asparagus and cactus, have leaves which are so small and scale-like that they are of no use in making nutrients. In such plants we find photosynthesis carried on in the stem.

82. How Leaves Are Arranged.—Notice how wide and flat a leaf is when compared with its thickness. It is modified to present as much surface as possible to the sunlight.

Examine the arrangement of leaves on a branch and you will find them placed so that they are either **opposite** each other, or **alternate** with each other. Frequently leaves which are arranged alternately form a spiral series along a branch. When arranged around the top of the stem like the petals of a rose, as in the dandelion, the **rosette** arrangement results. In an attempt to

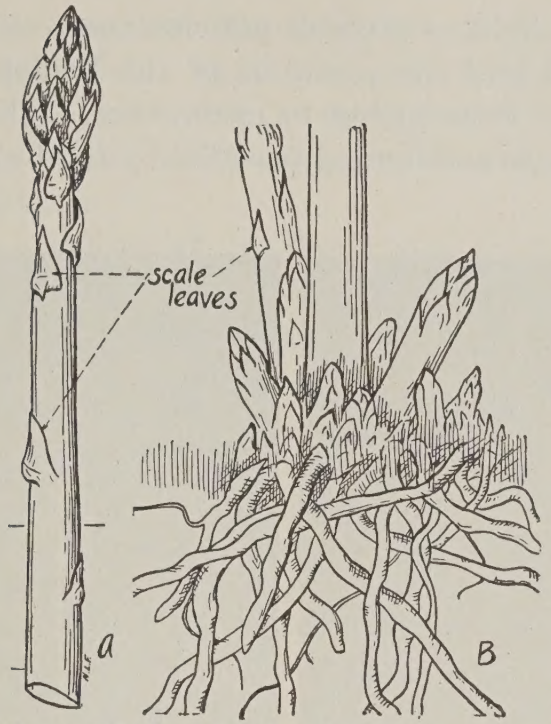
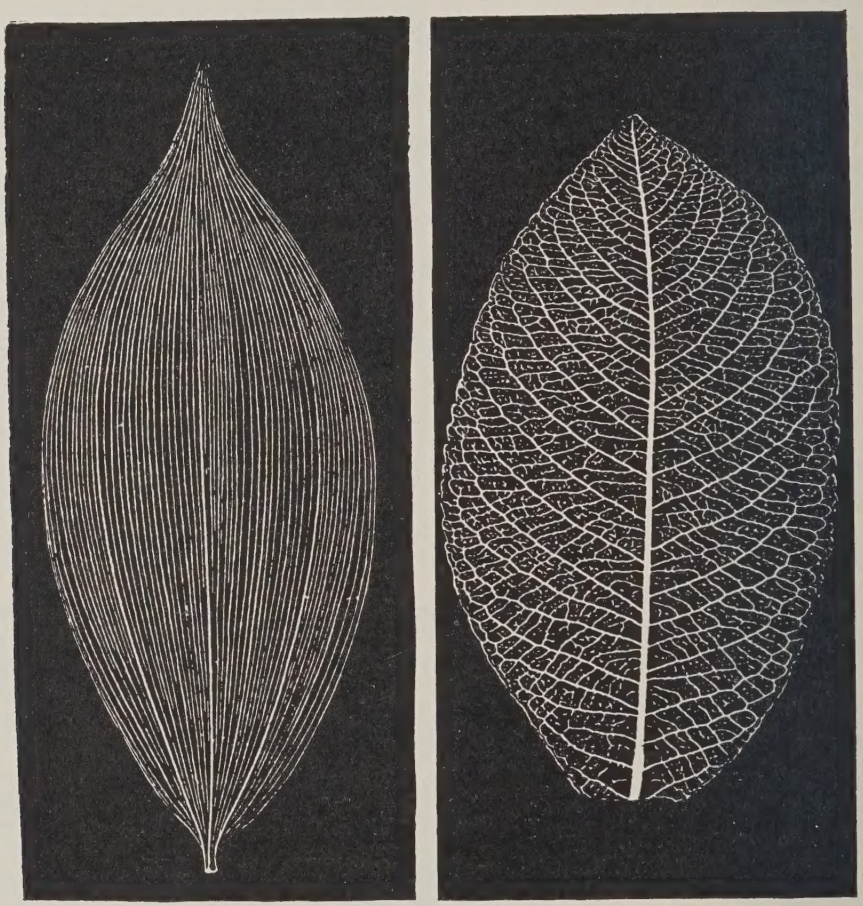


FIG. 35.—Asparagus. The leaves have been reduced to scales. Photosynthesis is carried on in the stem. *A*, a young shoot. *B*, fibrous roots and shoots arising from them. (*Harshberger.*)

FIG. 36.—Rosette arrangement of leaves of the "wild lettuce." This plant is believed to be the kind of plant from which all varieties of garden lettuce have come. (*Gager.*)

obtain as much light as possible **petioles** (*pet'-e-ōl*) or leaf-stalks may be twisted and the positions of the **blades** of the leaves changed in their relationship to each other. This may form a mosaic leaf pattern as often represented by the English ivy or the maple.



A *B*

FIG. 37.—The skeleton, or veins, of leaves. *A*, parallel venation (arrangement of veins) of Solomon's Seal. *B*, pinnate venation of willow leaf. The geranium leaf represents the simple palmate type of leaf. (*Mottier.*)

83. The Movement of Leaves.—The ability of plants to move is well shown when leaves turn to face the light. Sometimes when a plant is set in a window, the leaves will turn toward the source of light within a few hours. A few kinds of plants found near the desert, where the sunlight is intense, turn the edges of the leaves to the light to reduce the amount received.

84. Classes of Leaves.—Running through the blade or wide part of the leaf are **veins** which are made of tiny tubes for conducting materials to and from the cells; they also stiffen the leaf. The veins unite in the petiole or leaf-stalk and finally merge in the twig and branch.

The leaves which exist as single structures, each with its own petiole are known as **simple** leaves. There are two principal kinds: first, **parallel-veined** leaves which have their veins arranged in nearly parallel lines, such as the grasses; second, the leaves with veins which branch again and again. These are known as **netted-veined** leaves. This second group is subdivided into (1) the **pinnately** veined leaves which have a midrib with veins branching from it, and, (2) the **palmately** veined leaves in which the veins branch from the top of the petiole much as the bones of the hand extend from the wrist. From this fact we get the name.

85. Sometimes in order to permit sunlight to reach the lower leaves or to prevent the tearing of very large leaves by the wind, there are divisions so that the leaf becomes **compound** and is made up of several leaflets instead of having a single blade. The compound leaves are arranged in two groups as the simple netted-veined leaves are, although here it is the arrangement of leaflets and not veins which determine the name. That is, if the leaflets branch from a midrib as in the rose, the leaf is **pinnately compound**; if the leaflets branch from the top of the petiole as in the clover or oxalis, the leaf is **palmately compound.**

86. Later, when we study seeds, we shall learn that there are two principal kinds. One kind has a single seed-leaf, or **cotyledon** (*kot-il-e'-don*), and this structure gives the name **monocotyledon**, "one-cotyledon", to a large group of plants which includes the grasses and grains. As a rule, these plants have leaves with veins which run the entire length of the leaf and are nearly parallel with each other. In the other principal group, most of the plants develop from seeds which have two cotyledons. These **dicotyledonous** plants have netted-veined leaves, either pinnate or palmate and either compound or simple.

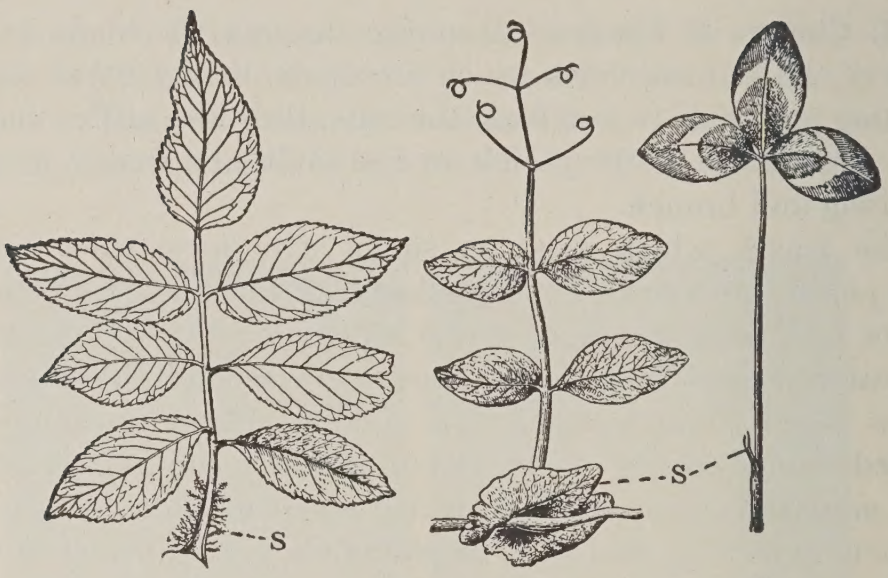


FIG. 38.—Different forms of compound leaves. *A*, pinnate leaf of rose. *B*, leaf of pea with large stipules, *s*. *C*, leaf of clover, with small stipules. (*Mottier.*)

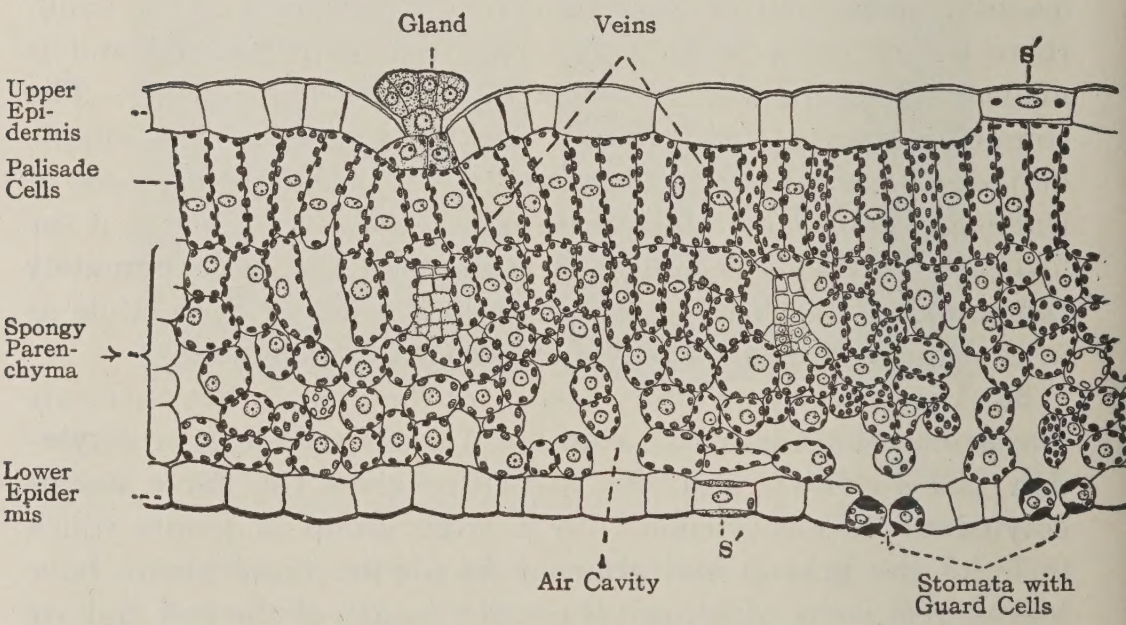


FIG. 39.—The leaf of the lilac, cut vertically to show the internal structure. *s'*, stoma. (*Mottier.*)

87. How Leaves Are Made.—The outer layer of cells makes up the **epidermis,** which is used principally for protection. On the surface of many kinds of leaves there is a very thin transparent layer made of **cutin** (*kū'-tin*), which is waterproof. This substance is secreted by the epidermal cells. Underneath the epidermis there is a layer of elongated **palisade cells.** Like the epidermis, these serve to protect the cells beneath them from too much light. They also contain chloroplasts for carrying on photosynthesis. (See Fig. 39.)

There is a definite limit to the amount of light a plant can use without becoming damaged. There is a relationship, therefore, between the development of palisade tissue and the amount of illumination. A plant growing in a shaded spot would have much less of this kind of tissue than a plant adapted for living in direct and intense sunlight.

88. Making up the center of the leaf are **spongy cells,** loosely arranged so as to admit air among them. It is through this layer of cells that we find veins running. On the lower surface of the leaf there is another layer of epidermis with its secreted cutin on the outside.

89. The Stomata.—Scattered among these epidermal cells are many slit-like openings, the **stomata.** Surrounding each stoma are two guard cells, one on either side. The guard cells are adapted for absorbing water rapidly. Light is the principal stimulus which controls the action of a stoma. In the daytime the guard cells swell with accumulated water and pull apart, thus allowing the leaf to release its contained water, besides allowing for a transfer of gases. When there is little or no light, as at night, the guard cells collapse and nearly close the opening or stoma. Among many plants the stomata do not close in light although the rapid loss of water may result in wilting or even death.

90. It has been estimated that there are 60,000 to 250,000 stomata on each square inch of surface, depending on the kind of leaf. They are mostly on the under side of the leaf. Leaves of plants in very dry places which have their edges to the sun to

help prevent excessive loss of water, have about an equal number on each side of the leaf. Can you tell why the floating leaves of water plants have stomata only on the upper side?

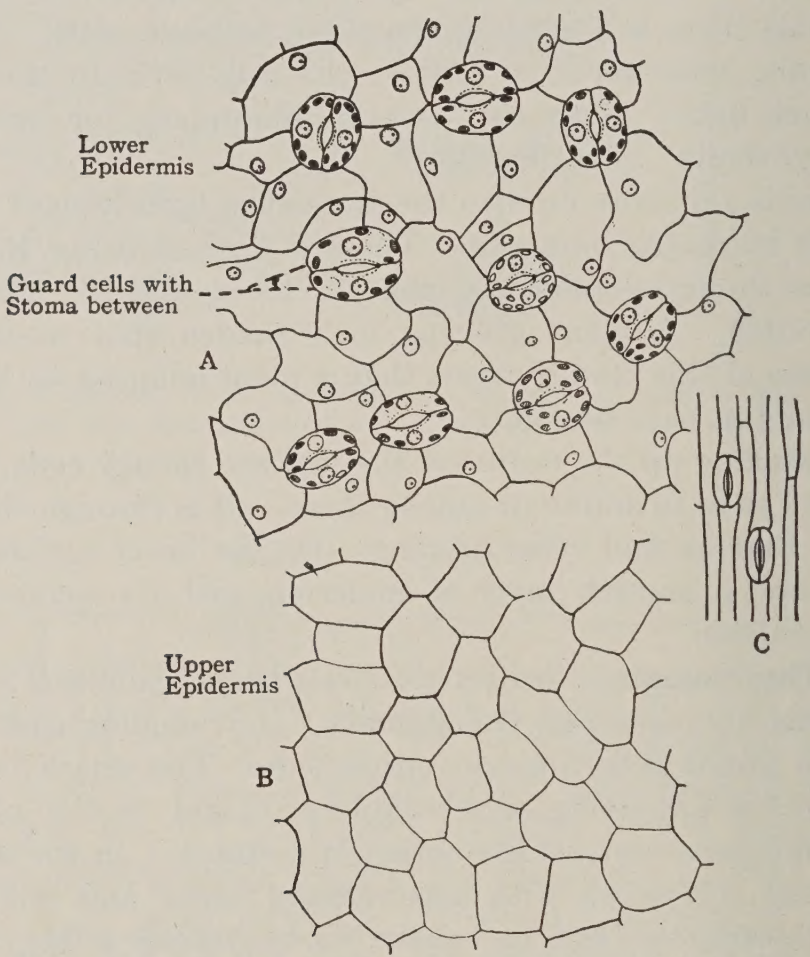


FIG. 40.—*A*, the under surface of a Lilac leaf. The guard cells are turgid and the stomata are open. *B*, upper surface of same kind of leaf. *C*, under surface of lily leaf, showing stomata closed. (*Mottier.*)

91. Transpiration.—Water is used in many of the organic processes. Since it forms the greater part of the tissues it must be constantly replaced as it is used. In the soil it serves to dissolve the mineral substances so that they may be absorbed by the roots and transferred through the stem to the leaves. This water passes out from the leaves through the stomata in the form

of water vapor and may affect the climate by increasing the amount of moisture in the air when the leaves are numerous, as in a forest.

92. This process, known as **transpiration,** may be demonstrated by placing a potted plant in an air-tight container, such as a glass bell jar. The soil should be covered with sheet rubber so that no water may escape. Within a few hours moisture will gather on the inner surface of the jar, frequently in a quantity sufficient to make drops. As all other sources are excluded, this moisture must have come from the leaves and stem.

93. Leaves Which Have No Chlorophyll.—Not all leaves are green. Perhaps you have seen the plant "Indian Pipe" or, as it is known in some localities, "Ghost Flower." All parts are white and nearly translucent. There is no chlorophyll present. If you were to look for one you would need to search in a place where the soil contains organic material such as dead leaves and decayed wood. The absence of chlorophyll makes it impossible for this plant to make its own food from carbon dioxide, water, and minerals as green plants can.

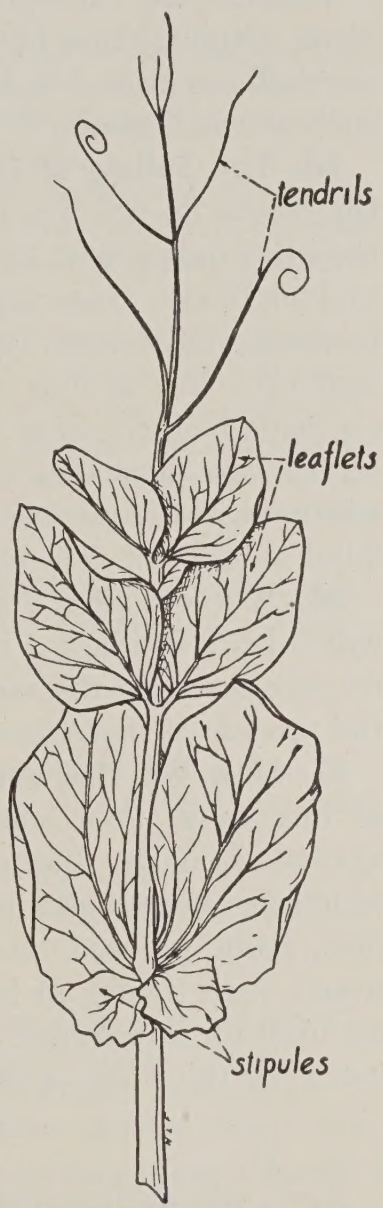


FIG. 41.—In the pea plant the mid-rib of the blade is often extended to form a tendril. (*Atwood and Heiss.*)

94. How Leaves May Be Modified. Some plants have leaves modified for other functions besides photosynthesis. A climbing plant, such as the garden pea, needs some device for clinging to a trellis or the trunk of a tree; so some leaves are modified into **tendrils** which curl about

any projection available. Other plants such as the barberry have certain leaves modified as **thorns** for protection.

Usually the function of reproduction is carried on by the seeds, although new plants may develop from the stem or root as we shall see later. A few plants may reproduce from the leaves, such as the begonia.

95. The Falling of Leaves in Autumn.—Among many plants the leaves do not live as long as the stems and roots. Usually they live only a part of the year when materials are available for making food. Even in the conifers (*ko'-nif-erz*), such as the pine, hemlock, and spruce, the leaves are not "evergreen" in the sense that they live as long as the tree. The dying and drooping of the wide-bladed leaf of the deciduous (*de-sid'-u-us*) tree or shrub serves two purposes: first, transpiration is reduced during the winter season; and second, waste materials which have accumulated among the cells of the leaves are cast away.

96. When the leaves are dropped, the broken ends of the tubes which have conducted materials to and from the cells are sealed by substances in the sap so as to provide an additional check to the process of transpiration.

97. How We Use Leaves.—We depend upon leaves for much of our food. We sometimes eat the leaves themselves, as lettuce, spinach, and cabbage. More often we eat the food which has been made in the leaves but later stored in the stem, root, fruit, or seed, as in the potato (modified stem), turnip (root), corn (fruit), or bean (seed). Then, we have the leaves of tea used for a beverage and the leaves of tobacco used in several forms for the effect of the contained drugs.

Interesting Projects

1. Bleach Coleus leaves by heating them in denatured alcohol. Be careful not to let the alcohol ignite. When the leaves have become white, place them on a sheet or piece of glass and add a few drops of diluted iodine. Why are the parts of the leaves that were green now purple, although the other parts are stained brown?
2. Pin thin slices of a large cork stopper on opposite sides of a leaf which has not been removed from the plant. Do not cover the entire surface of the leaf. After allowing it to stand all day in the sunshine, bleach the

leaves with denatured alcohol, and test with iodine. Explain your results.

3. Make diagrams which will show the (*a*) alternate, (*b*) opposite, and (*c*) rosette arrangement of leaves.
4. Place a geranium plant in a window. Identify one of the leaves which faces the interior of the room by cutting a tiny v-shaped piece from the margin. By means of a series of diagrams drawn at intervals of twenty-four hours, show the change in position of your leaf.
5. Make a collection of leaves; mount each one on a separate sheet of paper and arrange according to the following classification; monocotyledonous or dicotyledonous; simple or compound; pinnate or palmate. Write the common and the scientific names under each specimen.
6. Place a cluster of Elodea plants in a dish of water which contains a goldfish. Allow the dish to stand in the sun for an hour or two. Remove a single leaf and place it on a slide with a drop of water and a cover glass. Under the compound microscope look in the cytoplasm for the moving chloroplasts. Make a drawing which shows the arrangement of the cells, the cytoplasm, and, with arrows, show the direction in which the chloroplasts are moving.
7. Cover with sheet rubber the soil and pot of a well-watered plant. Place it under a bell jar and seal the edge of the jar with vaseline. When a definite change has taken place explain its occurrence.

Review

1. Explain how carbohydrates are produced in green leaves.
2. Explain how plants replace the oxygen of the air that has been used up by the animals.
3. Describe the different arrangements of leaves on branches.
4. Name the important parts of a leaf, and state the function of each part which you have named.
5. Describe the function of the stomata.
6. How may leaves be modified for functions other than photosynthesis?
7. Why are all animals dependent upon the green plants for food?
8. Why do most plants with wide leaves drop their leaves in autumn?
9. What are the similarities between photosynthesis and the making of a product in a factory?
10. Why do leaves cease their labors of carbohydrate-making after dark?
11. How do leafless green plants carry on the process of photosynthesis?
12. What are the economic values of leaves?

Self-testing Exercise

Green leaves can make carbohydrates because they contain the substance (1) _____. Moisture is added to the atmosphere by a process

known as (2) _____. The flow of gases into and out of leaves is controlled by the action of (3) _____ cells in closing or opening the (4) _____. The process of carbohydrate-making is called (5) _____. In leafless plants this process is carried on in the (6) _____.

The broad, flat part of a leaf is the (7) _____; the structures which transport materials to and from the leaves are the (8) _____. The outer protecting tissue of a leaf is the (9) _____. Most of the production of carbohydrates takes place in the (10) _____ layer of the leaf.

Define

blade
carbohydrate
chlorophyll
chloroplast
compound leaf
cotyledon
cutin
dicotyledon
guard cell
leaf veins
monocotyledon
palisade cell
petiole
photosynthesis
stoma
tendril
transpiration

CHAPTER X

FLOWERS ASSIST IN THE PROCESS OF REPRODUCTION

98. If you have ever looked across a valley dotted with fruit trees in bloom, or have been encouraged and refreshed by the first flowers of spring, you have paid grateful tribute, though

FIG. 42.—Avalanche lilies in Rainier National Park. Note how near the snow line they grow. (*Courtesy of "The Milwaukee Road."*)

perhaps unconsciously, to a wise Creator who often combines two or more values in one of nature's products.

99. The first work of colored and scented flowers is to insure a transfer of pollen grains among those plants requiring the aid of insects. But many flowers depend on the wind for this transfer, and a few of the water plants permit the pollen to float on the

surface of the water to other similar flowers. It is probable that flowers which are not brightly colored or scented are as successfully pollinated by wind as those pollinated by insects. Therefore we see that the plant kingdom could have developed in such a way as to make colored and scented flowers unnecessary. How much in beauty and enrichment our lives would lack without them!

100. Wild Flower Protection.—Notwithstanding the work of societies for the protection of wild flowers, aided in some cases by state laws, there are many persons who appreciate them in the wrong way. By picking flowers which wilt within a short time, they not only prevent seed production but deprive others who may come later, from enjoying them. How much better it is to leave them in their natural surroundings, as we do the birds, for future admiration by ourselves and others. Persistent picking, which has become more common with the introduction of the automobile, has resulted in reducing to a marked degree the abundance of many wild flowers, such as the lady's slipper, and is checking the development of others.

101. How the Flower Is Made.—The similarity in position of certain flower parts and the leaves indicates that the flower is a modified branch. The relationship between the outer flower parts, the **sepals** (*se'-palz*) and the leaves is apparent because they are usually of the same color and have a similar arrangement of veins. Inside these leaf-like sepals are the **petals** (*pet'alz*), which in the insect-pollinated flowers are often brightly colored. Inside the petals the **stamens** (*sta'menz*) are seen with their pollen boxes or **anthers** placed at the top of slender **filaments.** In this adaptation for different functions the blade of the leaf has become the anther while the filament is derived from the petiole. The anthers are held in such a position by the filaments that an insect like the bee would find it impossible to get by them in order to reach the nectar at the base of the flower without getting some of the pollen grains on its body.

102. The **pistil** in the center usually appears to be a single structure, but upon close examination it is often found to be made

up of parts fused together. In many flowers the pistil has the same number of parts as there are sepals or petals. If you were to make a diagram of the arrangement of flower parts as is done in Figure 43, you would probably find a definite relationship both in number and arrangement. For example, the tulip has three sepals on the outside, modified to look like petals, three petals just inside and alternating with them, six stamens, and three fused parts to the pistil. The stamens and pistils are the *essential* parts of the flower because they are necessary for the formation of seeds. The other organs are known as *accessory* organs.

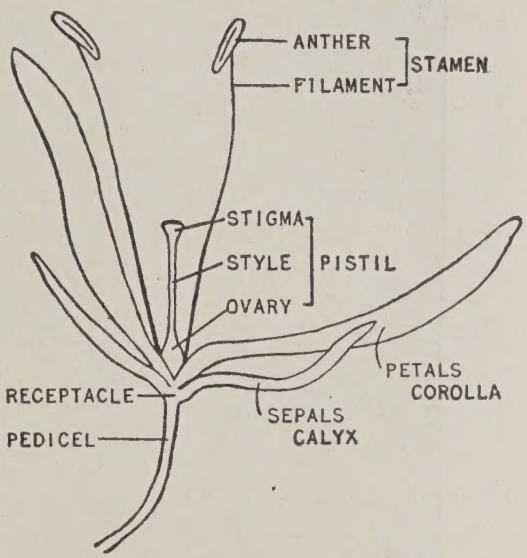


FIG. 43.—Diagram to show the parts of a flower. All the sepals taken together make up the calyx; similarly, all the petals make up the corolla. (*Atwood and Heiss.*)

103. A study of the structure of the pistil discloses several interesting adaptations. At the top there is a **stigma,** comparatively large and flat. This secretes a sticky substance so that any pollen grains falling on it are caught and held. Just beneath the stigma is the **style,** usually long and thicker than the filament. Inside this style, the cells are so loosely organized that the **pollen tube,** which develops from the pollen grain, is able to push its way readily. At the base of the pistil there is an enlargement, the **ovary.** Inside this the **ovules** are attached to the walls of the chambers in which they reside. These tiny but very important ovules are made up of structures which may develop into seed parts.

104. Within each ovule one special nucleus or **egg nucleus** is designed for union with one nucleus of the pollen grain, the **sperm nucleus.** When this union is completed and the nuclei are fused, the first cell of the new plant is formed. Therefore we find that every plant begins its existence as a single cell.

105. Pollen Grains.—Pollen grains from different kinds of plants differ from each other. A single pollen grain has two walls and several nuclei. They are produced in abundance because many never reach their destination. There are several agencies which aid in their distribution. They are very light in

FIG. 44.—Pollen distribution of the pine, a plant that depends on the wind for the distribution of its pollen. The cloud is composed of millions of pollen grains. (*Gager.*)

weight and the wind blows them about, like dust. Insects accumulate them on their bodies when they search for nectar. A few water plants are designed to catch water-borne pollen.

106. Pollination and Fertilization.—In some plants such as the violet, certain flowers never open at all, so that pollen can fall only on the stigmas of the same flowers, thus insuring self-pollination, while cross-pollination is being carried on by the

open flowers. If a plant were entirely and persistently self-pollinated, opportunity for variation would be much reduced because there would be no new hereditary factors introduced from other plants. Most flowers, therefore, have provision for cross-pollination of some kind, thus insuring the constant production of new varieties so that with changing climates or the

FIG. 45.—Flowers of the willow which contain stamens but no pistils. This condition makes cross pollination necessary. (*Photo by L. W. Brownell.*)

introduction of new types of competition, varieties may appear which will be successful under the new conditions.

107. Sometimes plants make elaborate provisions to secure cross-pollination and prevent self-pollination. A willow tree produces only one kind of flower, either staminate or pistillate, making it necessary for the pollen to be transferred from one tree to another. Among many plants the stamens are produced earlier than the pistils, or vice versa. And frequently

flowers are modified so that the pistils are much higher than the stamens, making it difficult for pollen to reach the stigmas of the same flowers.

108. After the pollen grain has landed on the stigma, pollination has been completed. Now the walls of the pollen grain, in contact with the sticky substance of the stigma are dissolved and **germination of the pollen** grain begins. A tube is formed

FIG. 46.—Flowers of the willow which contain pistils but no stamens. (*Photo by L. W. Brownell.*)

which grows through the loosely constructed tissue of the style and into the ovary. During this development the **generative nucleus** of the pollen grain divides into two **sperm nuclei.**

109. Within the ovary are specialized groups of cells attached to the ovary walls, and are known as **ovules.** Each ovule has two walls enclosing a clear protoplasmic material, the **embryo sac.** A large cell in the embryo sac, the **egg cell,** forms eight nuclei by a special kind of cell division. One of these nuclei is the **egg nucleus** which, if fused with a sperm nucleus, will form the

fertilized egg cell, the first cell of the new plant. Two other nuclei within the embryo sac known as **polar nuclei** fuse with one of the sperm nuclei to form the **endosperm** or food material for the tiny plant. Two protective coverings of the ovule form the protective covering, or **testa,** of the seed and the embryo sac

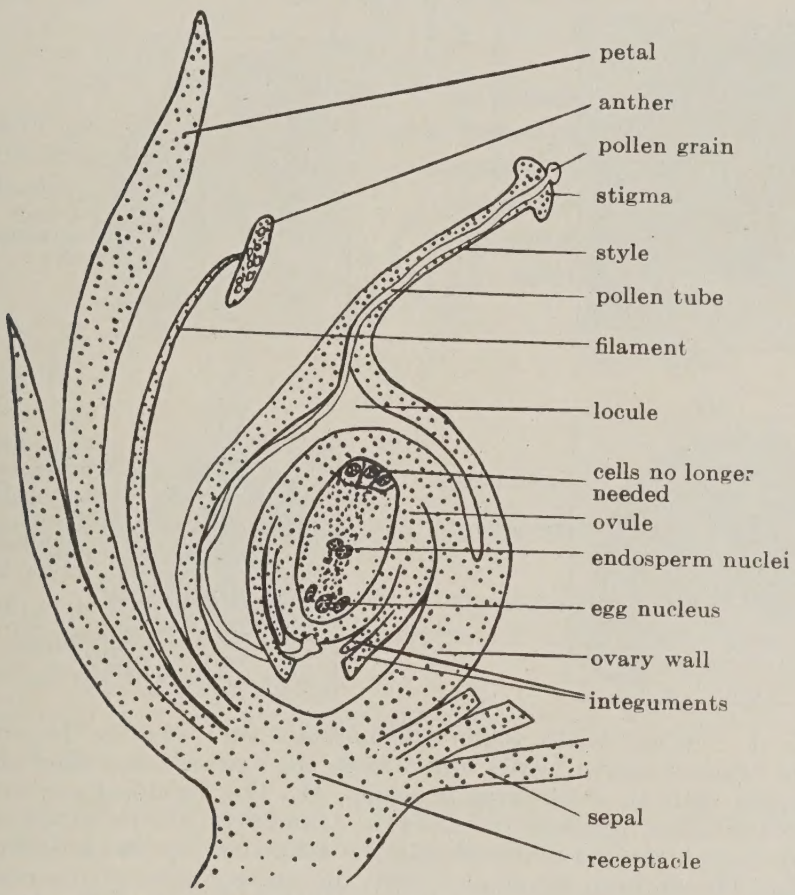


FIG. 47.—The development of the pollen tube from the pollen grain to the micropyle of the ovule. (*Atwood and Heiss.*)

becomes the one or more **cotyledons,** or seed leaves, of the embryo.

110. Now, to go back to the pollen tube which we left growing through the ovary, we find that it continues to grow on through the opening of the ovule, or **micropyle** (*mi'kro-pīl*). When the end of the tube comes in contact with the embryo sac, the walls of both structures dissolve at the point of contact, permitting

one of the sperm nuclei to fuse with the egg nucleus and produce the fertilized egg cell. **Fertilization** then, is the union of a sperm nucleus with an egg nucleus.

By cell division a group of cells is formed from the fertilized egg cell, and from this the **embryo** (*em'bre-o*) or young plant is

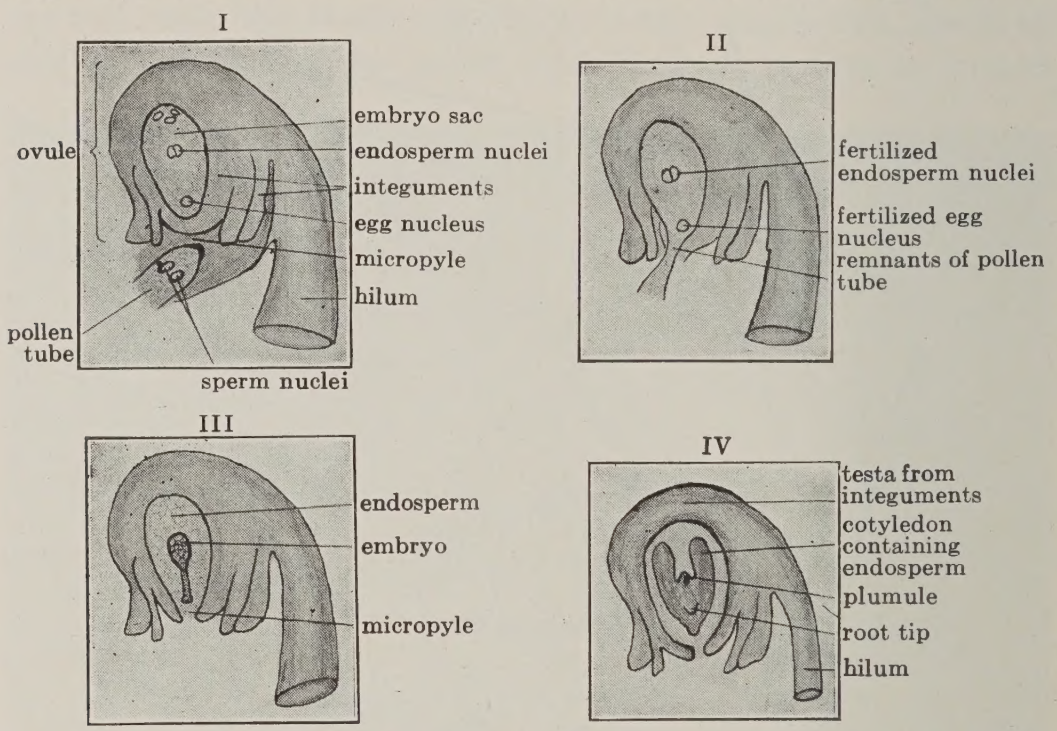


FIG. 48.—I. The end of the pollen tube bursts when it reaches the embryo sac. One of the released sperm nuclei unites with the egg nucleus; the other sperm nucleus unites with an endosperm nucleus. II. The fertilized egg nucleus, by repeated cell division, becomes the embryo. Similarly, the fertilized endosperm nucleus develops into food material which is later used by the growing embryo. III and IV. The embryo develops within the integuments of the ovule which become the testa of the seed. The seed is attached to the ovary wall by the hilum.

formed. When the embryo has developed sufficiently within the seed, it remains in a resting stage until conditions are suitable for the germination of the seed.

111. The endosperm which, as we have already noted, usually develops from the union of two polar nuclei from the ovule with a sperm nucleus from the pollen tube, is sometimes used very early in the development of the embryo, as in the bean. In plants of this type, the embryo occupies all the space within

the seed coat, or testa. In certain other plants, such as the corn, the endosperm remains until germination of the embryo occurs. It is then usually digested in a special kind of cotyledon, the **scutellum** (*sku-tel'um*) before being used.

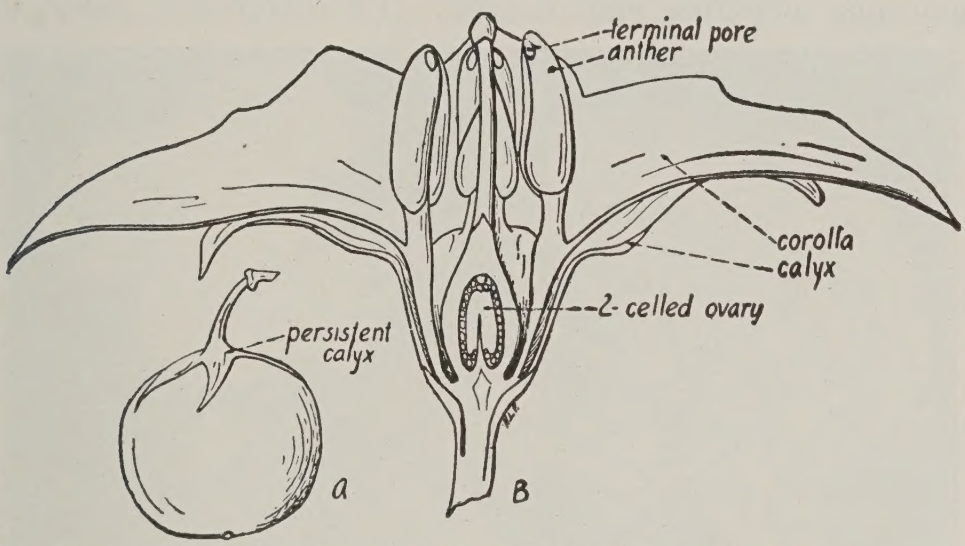


FIG. 49.—*A*, the potato berry or fruit which contains the potato seeds. *B*, in self-pollination the pollen grains are shed directly through terminal pores on the pistil. (*Atwood and Heiss.*)

112. We may summarize the steps of pollination and fertilization as follows:

I. Pollination—the transfer of pollen from anther to stigma.
   (*a*) Self-pollination.
   (*b*) Cross-pollination—principally by wind, insects, or water.

II. Germination of the pollen grain.
   (*a*) Production and growth of the pollen tube through (1) style, (2) into ovary, and (3) through the micropyle of the ovule to the embryo sac.

III. Fertilization.
   Union of one sperm nucleus with the egg nucleus to form the fertilized egg cell which is the first cell of the new plant.

113. Composite Flowers.—Some of our most common wild flowers are compound in structure and have many flower parts. The portion of the sunflower which we call the flower is really composed of several hundred florets or single flowers grouped in

one common head. An insect walking across such a flower would pollinate many more pistils in a shorter time than would be possible if the flowers were single. Consequently, the composites are very successful in their competition with other organisms, including man himself. The dandelion, daisy, and

FIG. 50.—The chrysanthemum is a composite flower which has been cultivated and admired for centuries. It is the national flower of Japan. (*Robbins and Ramaley.*)

thistle are other examples of these flowers which often become persistent and troublesome weeds.

114. After the Flower Has Served Its Purpose.—With the development of the seeds within the ovary, the flower parts no longer needed, such as the petals, sepals, stamens, stigma, and style, become much reduced in size, or drop off completely. The ovary wall thickens to form the fruit—our next subject for study.

Interesting Projects

1. Each member of the class should make a collection of common flowers, pressed, identified, and mounted on heavy paper or cardboard. Be a good citizen by learning which flowers are protected by law in your state and do not include these in your collection.
2. Place the pollen grains from different flowers under a compound microscope, and make sketches of the various shapes.
3. Make a list of different adaptations for pollination in the flowers you find.

Review

1. Why is the flower considered to be a modified branch?
2. What are the essential parts of a flower; the accessory parts?
3. How does the location of the nectar assist in the pollination process?
4. Describe the method by means of which a sperm nucleus finally meets and unites with an egg nucleus.
5. Which parts of the flower usually become parts of the fruit?
6. Why does nature take such great precautions to assure cross-pollination among many plants when self-pollination is easier?
7. How has the introduction of the automobile made protection of wild flowers more necessary?
8. What evidence indicates that the principal function of colored or scented flowers is to insure cross-pollination?

Define

anther
calyx
composite flower
corolla
cross pollination
egg cell
egg nucleus
embryo sac
fertilization
fertilized egg cell
filament
generative nucleus
germination of pollen
micropyle
nectar
ovary
ovule
petal
pistil
polar nuclei
pollen tube
pollination
scutellum
self pollination
sepal
sperm nucleus
stamen
stigma
style
testa

CHAPTER XI

FRUITS ASSIST IN THE DISPERSAL OF SEEDS

115. Have you ever stood in front of a fruit stand with all the varieties of fruit so attractively displayed before you? There on one side were the oranges, the bananas—both red and yellow, lemons, pears, and peaches, while in the middle of the stand, perhaps, were boxes of blackberries, currants, and plums. On the other side were cucumbers, tomatoes, and melons, nicely arranged and tempting you to buy. What a display! You just wanted to sample one of each kind.

116. But did you ever wonder from what part of the world each kind came? Not only what part of the world, but what sort of trees, bushes or vines produced them? And, finally, how were they formed on all those different plants and, if each one started as only a part of a flower, what changes took place to make it a fruit?

117. How the Fruit Is Formed.—You know that every flower contains an ovary. This is the beginning of our fruit. The ovary is a hollow case which contains one or more compartments, with tiny rounded bodies in each one. Each of the tiny bodies will normally develop into a seed, if fertilized. The fruit is the home of the seed, and is the final result of all that has taken place in the flower since it blossomed. It is just as if Nature had been looking forward, all the time, to assuring another generation by providing the seed. Not satisfied that plants shall live and blossom only this year, but that new plants shall continue to brighten our highways, fields, and gardens for generations to come, yes, and to provide us with foods, too.

118. If we remember our definition, that "the fruit consists of the ripened ovary with any other flower parts that may remain

attached to it", we shall see at once that a number of other things such as nuts, berries, kernels of corn, and many so-called

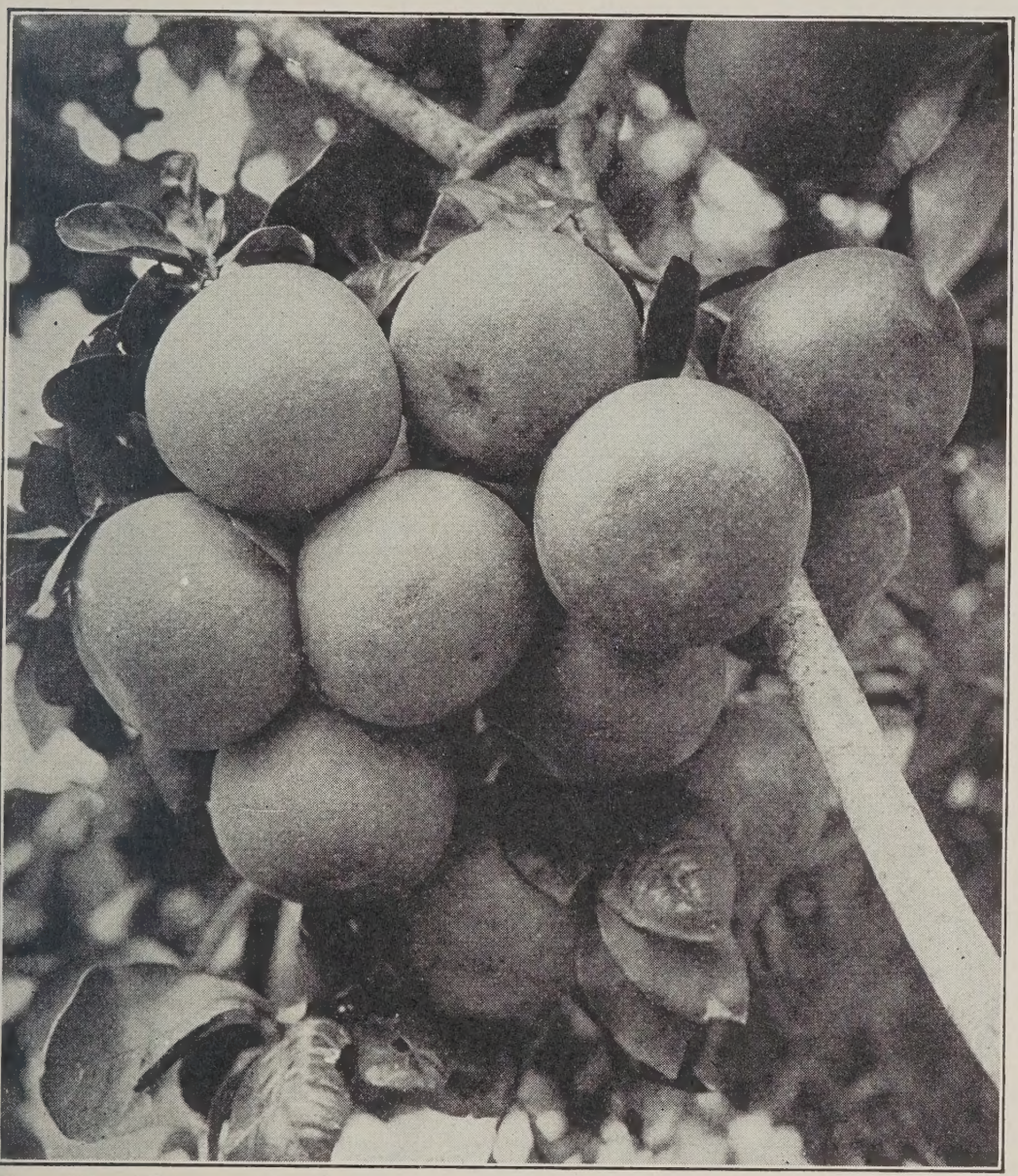


FIG. 51.—The grapefruit has been developed from a much smaller fruit. (*Robbins and Ramaley.*)

"vegetables", such as squashes and cucumbers, are really fruits, since they fulfill the requirements of the definition.

119. Kinds of Fruits.—But we have such a variety of fruits! Some, like the cucumbers and apples, are **fleshy.** Others, such

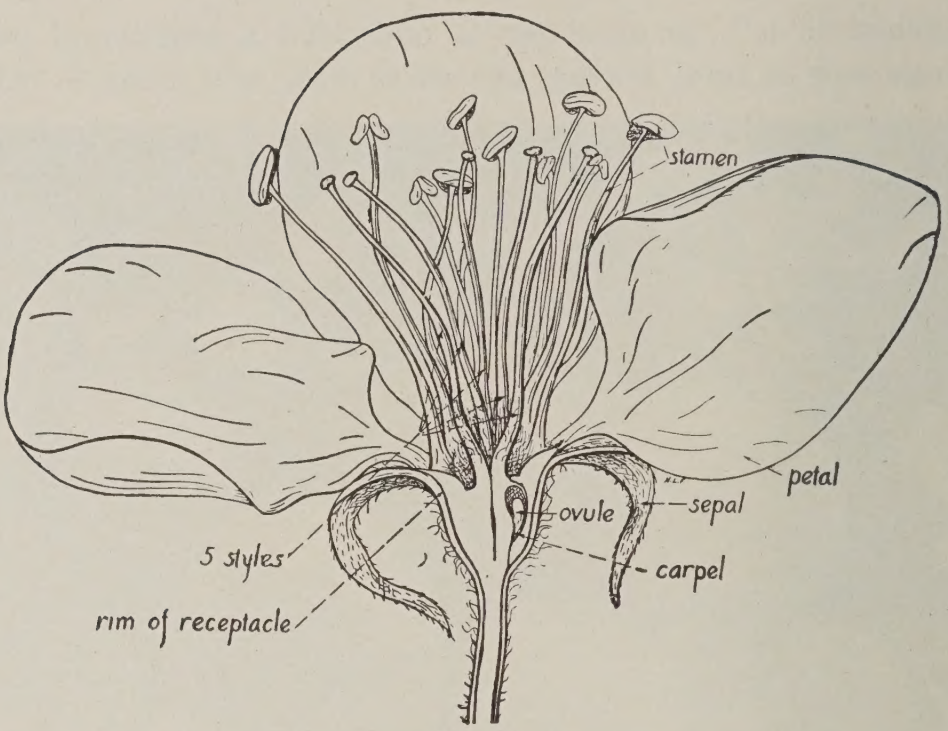


FIG. 52.

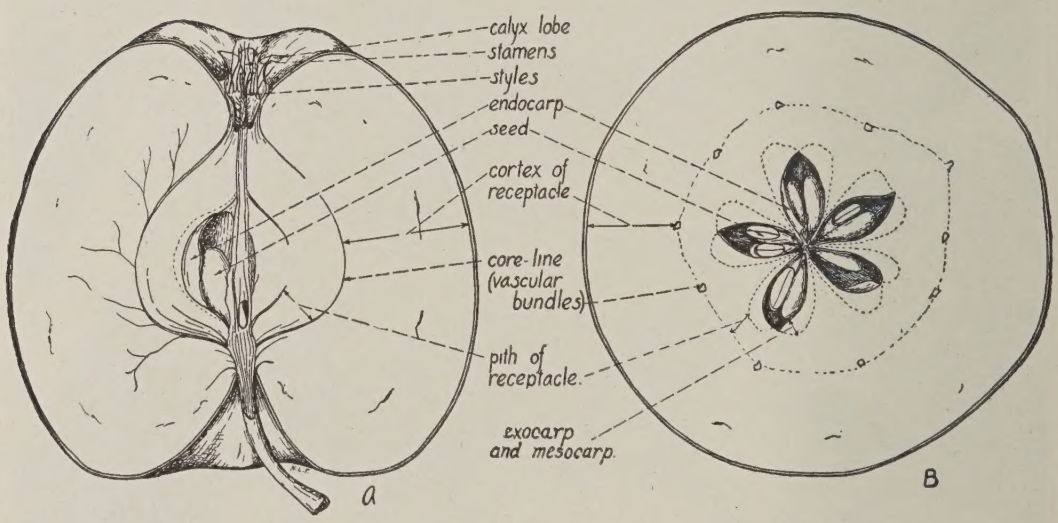


FIG. 53.

FIGS. 52 and 53.—The apple cut lengthwise and crosswise, and the flower from which it develops. Each of the five parts of the pistil has a carpel forming the walls of a locule. The carpels comprise the core of the apple. (*Atwood and Heiss.*)

as acorns and bean pods, are **dry.** The dry fruits are either **dehiscent** (*de-hi'-sent*) or **indehiscent,** according to their method of seed distribution. If dehiscent, they open for the discharge

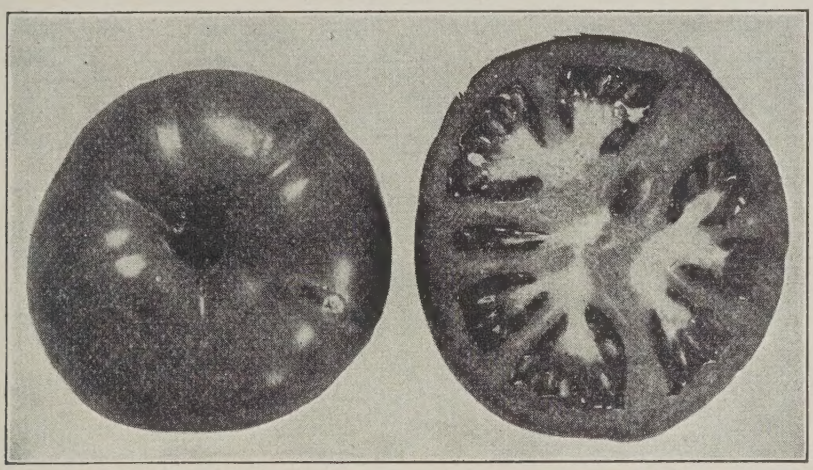


FIG. 54.—The ripened ovary, or fruit, of the tomato. The cut section of this fruit, which is a berry, shows the ripened ovules, or seeds, attached to the placentas. (*Gager.*)

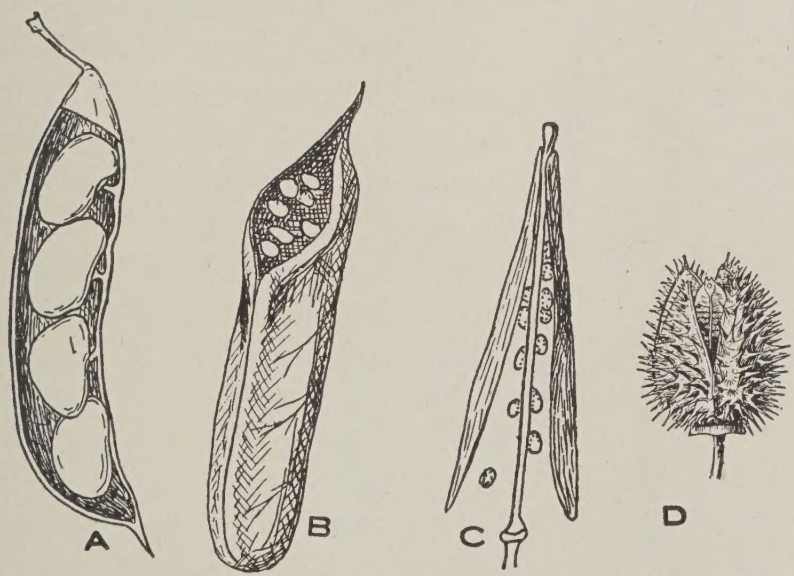


FIG. 55.—Four dehiscent fruits. *A*, pod of lima bean; *B*, follicle of monkshood; *C*, silique of mustard; *D*, capsule of jimson-weed. (*Atwood.*)

of seeds, as in the bean, pea, witch hazel, or violet; if they are indehiscent, as in the case of the maple samara, or kernel of corn, they have no well-defined places for opening.

120. Methods of Dispersal.—It is among the dry fruits that we find the most interesting adaptations for the dispersal of

Fig. 56.

Fig. 57.

Figs. 56 and 57.—Indehiscent fruits. Samaras of maple (left) and elm (right). (*Atwood.*)

either fruits or seeds. Dispersal is one of the plant's great problems because the plant cannot move about to distribute its seeds. Many of the seeds would otherwise fall to the ground directly under or near the parent plant. The thousands of maple seeds from the samaras could not possibly grow into trees within the space of a few square yards that surround the parent maple tree. Let us see how nature solves this problem.

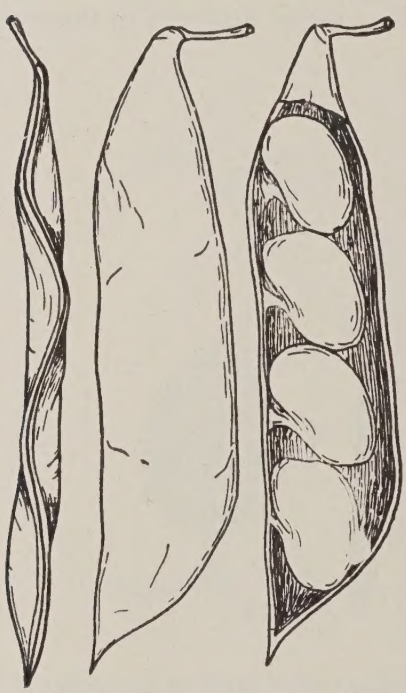


Fig. 58.—The bean pod is an example of a fruit in which the carpels still resemble leaves from which they were derived. (*Atwood and Heiss.*)

121. In the bean, for example, the ovary wall or pod dries up after the seeds ripen. It becomes brittle and finally flies open, casting the seeds about it on the ground. So does the wood sorrel. The violet fruit develops into a capsule which opens with explosive violence, scattering the seeds about. The burdock provides its seed-bearing structures with hooks so that they may become

attached to the fur of passing animals or to the clothing of men, often traveling in this way for long distances before being

FIG. 59.—Milkweed pods and the tufted seeds. Note the adaptations of the pod for releasing the seeds, and of the seeds for dispersal. (*Atwood.*)

brushed off. Dandelions and thistles provide their seeds with parachute-like structures with which they sail away over the fields on the first breeze. And surely you have seen the tumble

weeds. They go rolling across our lawns in the fall every time the wind blows. And so it goes. Every single species has been taken care of, each in the way best suited to it. Should we take it all for granted, or should we pause to see the wonderful ingenuity that is shown in all these varied forms?

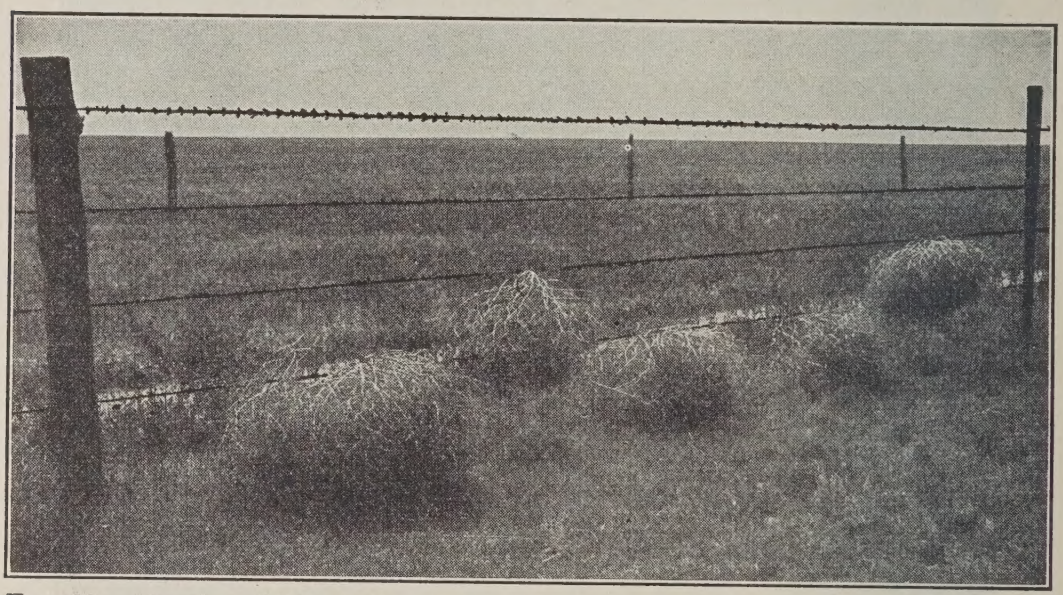


FIG. 60.—Russian thistle is sometimes rolled along the ground as a tumbleweed, providing in this way for the distribution of the seeds. (*Harshberger.*)

122. Doubtless you have noticed how unlike the growing fleshy fruit is that same fruit when it has ripened. While becoming ripe, the color remains inconspicuously green, like the leaves, and the fleshy part is sour or bitter so that it is distasteful to the animals, including the birds. It would defeat the whole purpose of the fruit if the seeds were scattered before enough food had been stored in the cotyledons or if the embryo were still incomplete. But when the seeds are complete in the chamber or **locule** (*lok'-ūl*) of the ovary in which they reside, the fact is broadcast to all the world. Nature advertises her wares by the use of bright, contrasting colors. Man has copied this method for attracting attention, as you will note from any magazine or billboard advertisement. Apples become a bright, shining red or yellow, and contrast strikingly with the dark green of the leaves. Oranges gleam like bits of sunlight

in their dark setting. The bright red of the cherry invites any passing bird or other animal to eat it. And that is exactly as Nature planned, knowing that the seeds will be deposited in many places. Sometimes the fleshy part is eaten and the remainder containing the seeds is thrown away, as in the apple or peach. But even if the seeds are swallowed, as the birds often do, no harm is done because the seed coats are impervious to the action of the digestive juices and are therefore not digested or changed in any way.

FIG. 61.—The squirting cucumber discharges its seeds as it breaks away from the stem. (*Atwood.*)

123. The Development of New Kinds of Fruits and Their Transportation.—Fleshy fruits are rich in vitamins, fruit acids, starches, sugars, proteins, and minerals. The vitamin content alone would make them worthy of an important place in our diet. Most nuts contain a high percentage of proteins and fats.

124. The work of improving fruits by making them larger or the flavor better or by developing disease-resisting varieties is going on continually. Careful selection, artificial pollination, and grafting or budding are methods frequently used. This is a field of biology in which there are many opportunities for persons who are interested and who are qualified to carry on the work.

125. The transportation and distribution of these products, so that we may have fresh fruits from many sections of the world at any time of the year, is one of the greatest achievements of the twentieth century. Fast freight trains and freight boats have been developed; refrigeration methods have been improved;

better methods of insect and plant-disease control have been introduced—all contributing toward this common goal.

126. Fifty years ago only persons of wealth could afford to serve fresh fruits from other parts of the world during the winter

FIG. 62.—Luther Burbank (1849–1926) developed many new varieties of fruits and flowers. (*Underwood & Underwood.*)

months. But what is the situation, today? Just think again of that fruit stand, where we started.

Interesting Projects

1. Cut one apple lengthwise, and another apple crosswise. Draw the cut sections and label all parts. Which parts are found in both sections?
2. Soak corn grains in water for several hours. Cut one grain parallel to the flat surface, and another grain parallel to the edge. Draw both sections and label all parts.
3. Cut several more corn grains lengthwise, as above. Soak one in dilute iodine; one in Fehling's solution; and one in nitric acid and later in ammonia. Make drawings to show the location of starch, grape sugar, and protein in the corn fruit.
4. Make a collection of dry fruits which show different adaptations for seed dispersal.

Review

1. How would the lack of adaptation for dispersal affect the distribution of fruits?
2. How are fruits classified? Give examples of each.
3. How do birds assist in the distribution of fruits?
4. Why are new kinds of fruits constantly being developed by man?
5. Why are we able to have a greater variety of fruits at moderate prices than our grandparents could have?

Define

budding
dehiscent fruit
dry fruit
fleshy fruit
grafting
indehiscent fruit
locule
vegetable

CHAPTER XII

THE ADAPTATIONS OF THE SEED CONTRIBUTE TO THE SUCCESS OF ALL HIGHER PLANTS

127. It would be difficult to believe that a tiny seed had within itself the possibility of becoming an immense tree if the fact

FIG. 63.—Wheat is raised extensively because it is the source of flour. (*Courtesy of International Harvester Co.*)

were presented as something recently discovered. But familiarity causes us to accept many of nature's wonderful transformations without question and too frequently without interest. Let us see how this transformation takes place.

128. Kinds of Seeds.—Seeds are of two principal kinds. Those plants with parallel-veined leaves (Chapter IX) have

seeds containing one **cotyledon,** or seed leaf as a part of the embryo and are known as **monocotyledonous** plants. The **dicotyledonous** plants are those with two cotyledons in the

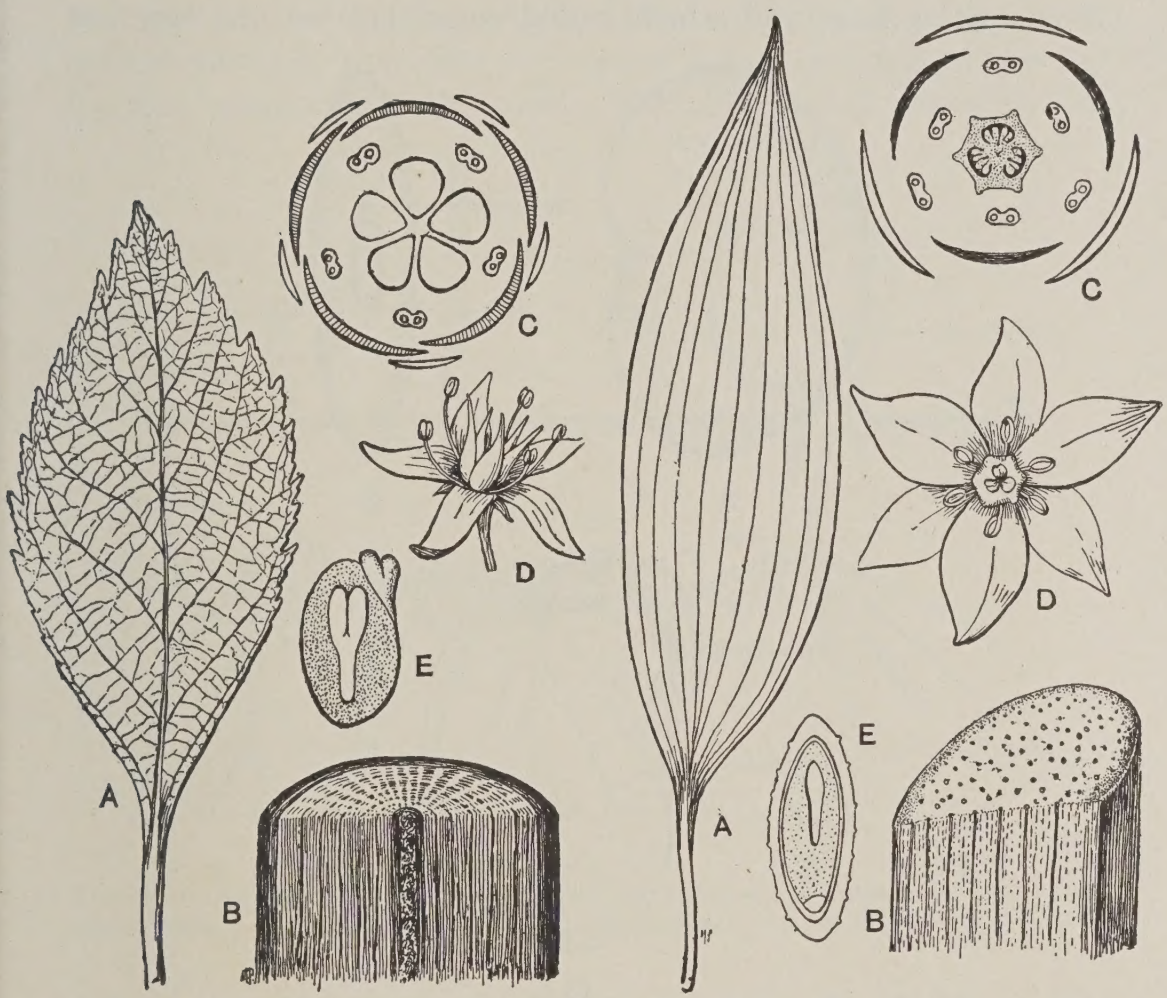


FIG. 64.—Drawings to show the differences between the stems, leaves, flowers and seeds of monocotyledonous and dicotyledonous plants. In each case *C* represents a flower cut across to show the arrangement of the sepals, petals, stamens and ovary. (*Atwood and Heiss.*)

embryo. As we have seen, this type of plant has netted-veined leaves.

129. A Dicotyledonous Seed.—If you will soak a bean seed in water for a few hours the covering or **testa** will soften. Then with a pin cut through the testa and remove it. Now it is possible to see that the seed is a complete but undeveloped plant.

Pull the two large portions or cotyledons apart, noting the point of attachment. Extending from either side of this point are two kinds of structures. The tiny parts which are apparent as leaves, if you use a lens, and which would some day become the first

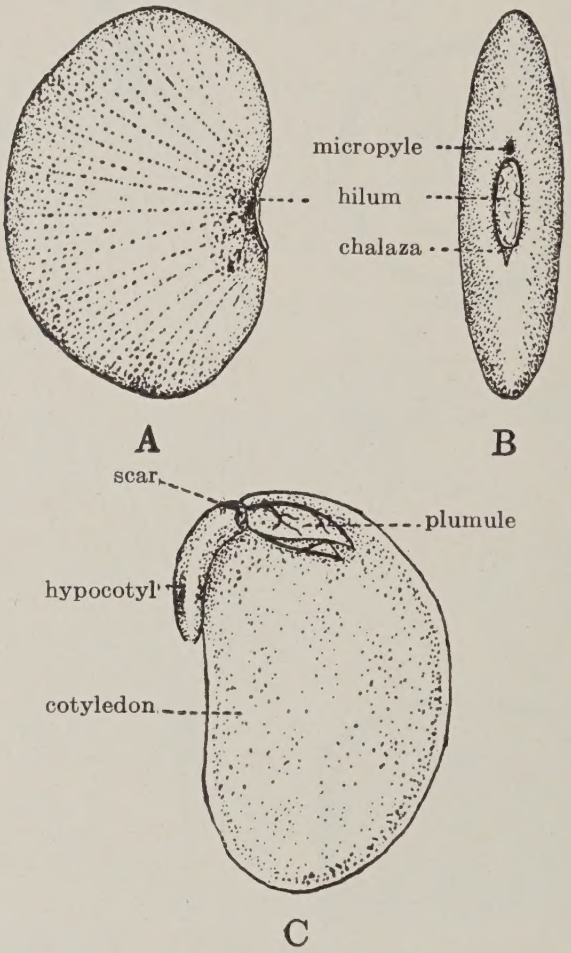


FIG. 65.—Lima bean. *A*, side view; *B*, looking toward the place of attachment; *C*, the embryo with one cotyledon removed to show the arrangement of the other parts. The testa has also been removed. (*Mottier.*)

true leaves, are known as the **plumule** (*ploom'-ūl*). They are attached to the stem-like **hypocotyl** (*hi-po-kot'-il*) which is designed to become the root and a portion of the stem.

130. The Development of the Bean Seedling.—The interesting development of a plant may be watched by planting a few bean seeds in a box of soil. Moist sawdust may be used if soil is not

available. Water seeps through the micropyle (where have you used this word before?), and causes the cotyledons to expand. This in turn ruptures the testa or seed coat, thus allowing the development of the hypocotyl. This structure develops in an arched position, the lower end being pushed down into the soil for the formation of the root. After the top of the arch has

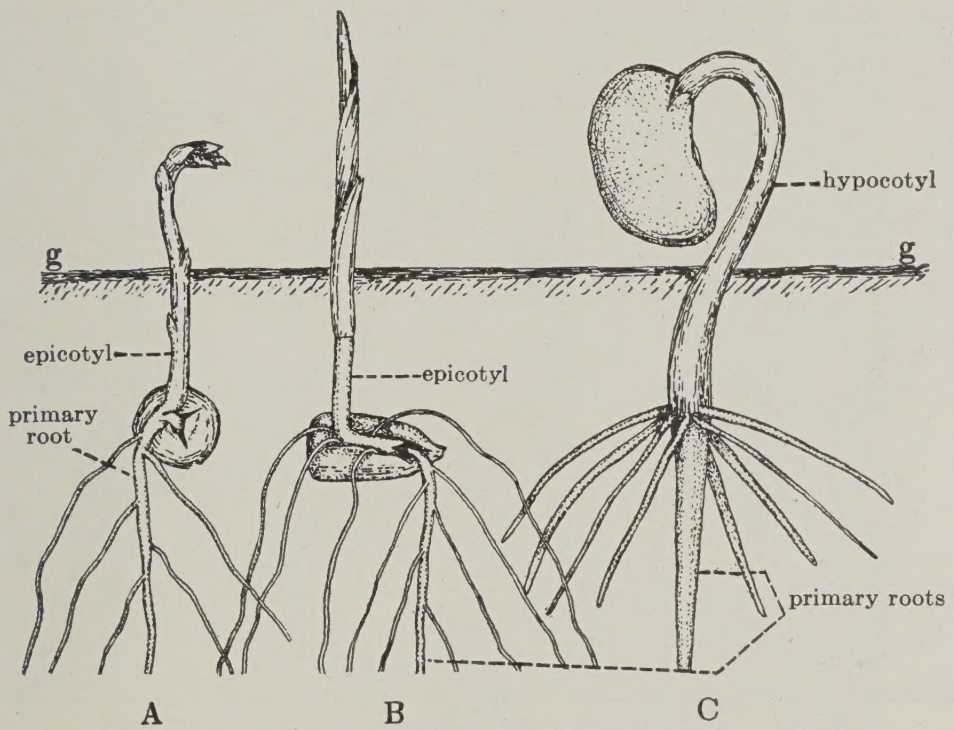


FIG. 66.—Diagram to show how different seedlings grow through the surface of the ground. *A*, garden pea; *B*, corn; *C*, lima bean; *g*, ground level. (*Mottier.*)

pushed up through the surface of the soil, the growth of the hypocotyl pulls the cotyledons through the surface, too, with the plumule still between them. During all this development the cotyledons have been constantly decreasing in size because their stored food has been used to make new cells necessary for growth. When freed from the soil, the cotyledons make chlorophyll, (the green coloring matter), and build carbohydrates for a time while the true leaves are developing from the plumule. Finally the cotyledons are reduced to scale-like structures and drop off.

131. The photograph (Fig. 67) shows the typical development of the squash seedling. But variation is a rule of nature and just as there are no two individuals of any kind that develop exactly alike, neither are there any two seedlings which develop in **exactly** the same way. Make a series of drawings of the development of one of your seedlings, showing the same stages

FIG. 67.—Development of the squash seedling. (*Atwood.*)

but indicating how your plant differs from the typical one pictured here.

132. A Monocotyledonous Fruit.—Another familiar agricultural product, corn or maize, is a member of the monocotyledonous group. It has parallel-veined leaves, a stem differing in structure from the dicotyledonous stem in several ways as we shall see later, and the embryo has but one cotyledon, as the name indicates. Although corn kernels are often called "seeds", each kernel develops from a single ripened ovary. Therefore it is a fruit. The cob is derived from the flower stalk.

133. On one side of the corn fruit there is an oval white area, in the center of which occurs a raised portion. If this portion is

cut through lengthwise and a lens is used, several structures become evident. The outside covering is the ovary wall.

Fig. 68.—Maize, or Indian corn. At the left is the flower stalk with the pistillate flowers or "ear"; at the right are the staminate flowers, or the "tassel." The "silk" is composed of the styles. Therefore it is necessary for a pollen grain to pass through the entire length of a "thread of silk" to reach the ovule. (*Robbins and Ramaley.*)

Occupying most of the interior area there is a stored food or **endosperm.** Near the point of attachment of the fruit we find the embryo as a white area or cotyledon, within which appear

two v-shaped structures, the hypocotyl below and the plumule

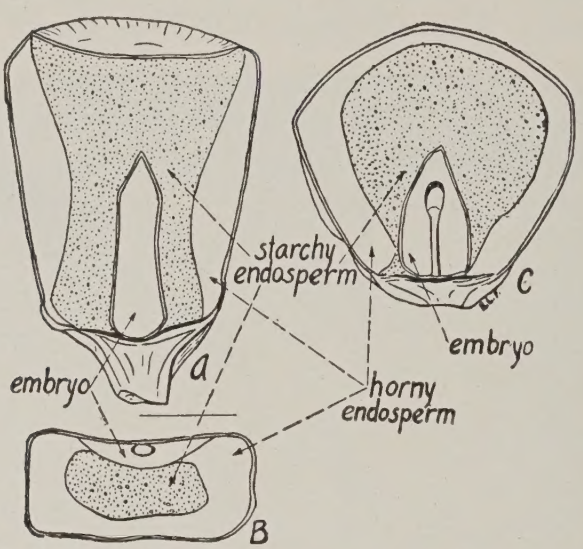


FIG. 69.—Sections of corn grains, or fruits. *A*, dent corn, lengthwise section; *B*, dent corn cut across; *C*, flint corn cut lengthwise. (*Atwood and Heiss.*)

above. The cotyledon of the corn is given a special name, **scutellum,** because it resembles a shield in shape. The function of this structure is to digest the food of the endosperm so that it can be used by the remainder of the embryo. The absence of a similar structure in the bean indicates that the stored food becomes available as soon as it is liquefied, thus making it possible for the bean and other seeds without a scutellum to get an earlier start when germinating.

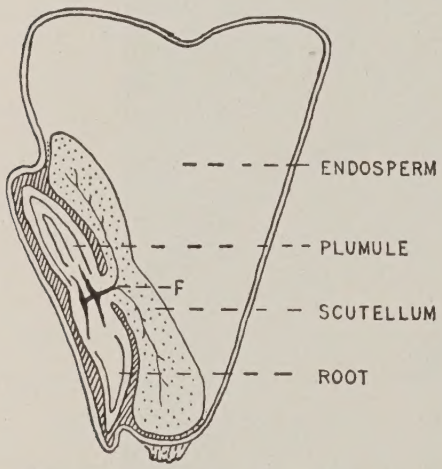


FIG. 70.—A lengthwise section through a germinating grain of corn. *F*, fibrovascular bundles through which food material passes from the scutellum to the remainder of the embryo. The scutellum is the cotyledon. (*Atwood and Heiss.*)

134. We have seen in Sections 120–122 some of the ways in which many of the fruits are scattered. In order that the various kinds of plants may reach favorable locations it is often equally necessary for the seeds to become adapted for dispersal.

Figure 71 shows a few of the many devices employed by seeds for getting themselves scattered about into new locations. Their hooks and spines cling to our clothing and to the fur of animals. The pappus of such seeds as the thistle and dandelion drifts away through the air. The winged seeds of the ash and maple never fall straight downward, but go spiraling off across the lawns and fields soon after they are ripe.

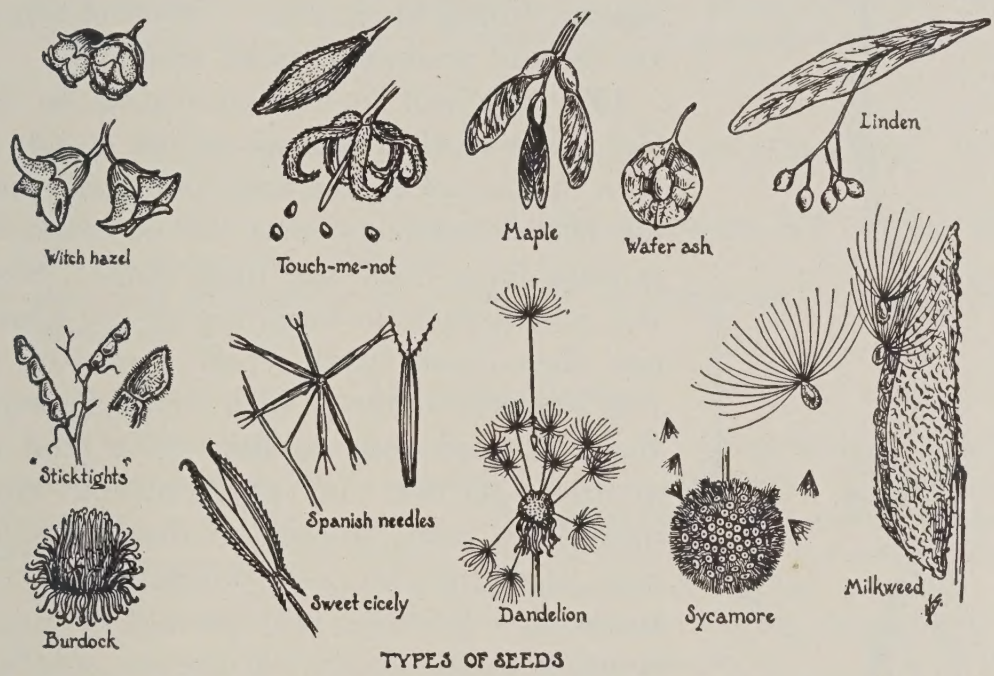


FIG. 71.—Seeds show many different adaptations for dispersal. (*Copyright by The General Biological Supply House, Chicago.*)

135. The Development of the Corn Seedling.—If you will allow some corn seedlings to develop along with your beans, you will note several differences. The hypocotyl grows straight down to form the root. The plumule grows up and breaks the surface of the ground, leaving the remainder of the fruit in its original position. The food material of the endosperm and scutellum is used in the growth of the corn seedling just as the stored food of the cotyledons of the bean is used for its development.

136. The Digestion of Food in the Seed or Fruit.—Much of the food that is stored in the seed or in the fruit must be altered

by a process of digestion before it can be used. In plants, the change from starch to grape sugar is accomplished by an enzyme (*en'-zīm*) known as diastase (*dī'-as-tās*). The enzymes are fluids found in both plants and animals, which are capable of bringing about important digestive changes without being used up rapidly during the process. These enzymes are usually present in small amounts.

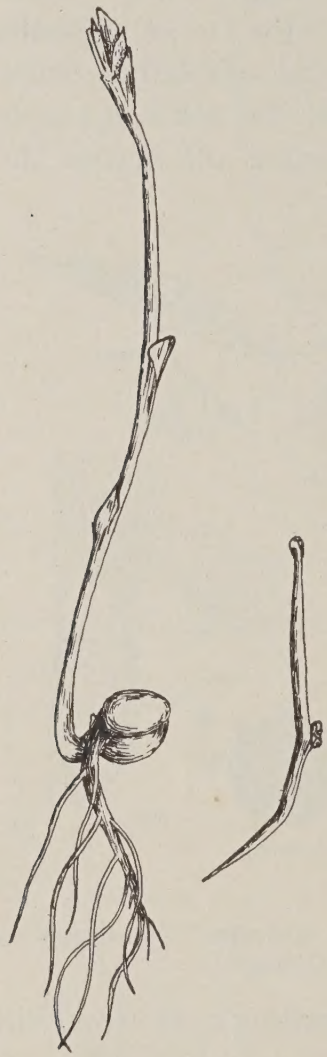


FIG. 72.—The cotyledons were removed from the pea seedling at the right, and were left on the one at the left. The two seedlings germinated at the same time. This experiment shows the value of the food stored in the cotyledons. (*Atwood.*)

137. You will find it interesting to see the effect of this enzyme on the starch of corn fruits. The diastase you will need for this experiment may be obtained in powder form from any drug store. Soak the corn kernels in water for several hours, and then crush them. Test a portion of this crushed material with Fehling's solution. Record your results. Now add to another portion of the crushed corn material a small amount of diastase solution, made by adding the powdered enzyme to water. After ten minutes add Fehling's solution to the combined diastase solution and crushed corn solution. Record your second results, and complete the written account of the experiment with, (*a*) the material and apparatus needed for the experiment, (*b*) the procedure followed, (*c*) the results obtained, and (*d*) the conclusions based on the results obtained. This experiment represents one of the many complex processes which make possible the continuance of life in organisms.

Interesting Projects

1. Make a collection of seeds. They may be kept in small vials which can be obtained at any drug or department store. Identify and label each

kind. Reference book titles can be found in the appendix of this book.

2. On a plain map of the United States, use different water colors to indicate the areas where corn, wheat and cotton are raised extensively.
3. Soak for several hours the seeds of sunflower, pea, bean, and corn grains. Plant these seeds in flower pots and moisten the soil occasionally. Does the same part of the embryo break through the surface of the ground in each case? Make drawings of the seedlings when (*a*) very young, (*b*) when half grown, and (*c*) when mature. Label all parts and show how certain parts change as the young seedlings become mature seedlings.

Review

1. Which parts of the ovule of the flower are found in the seed? What changes have taken place in each part?
2. In a tabular form list (*a*) the dicotyledonous plants, and (*b*) the monocotyledonous plants you know.
3. How does the development of the corn seedling differ from that of the bean seedling?

Self-testing Exercise

Seeds of dicotyledonous plants have (1) _____ cotyledons, and seeds of monocotyledonous plants have (2) _____ cotyledon. The covering of the seed is the (3) _____. It was developed from the coverings of the (4) _____ of the flower. The first true leaves of the seedling come from the (5) _____. They are attached to the stem-like (6) _____. The corn kernel is a fruit because it is developed from the (7) _____. The corn cob is derived from the (8) _____. In the corn kernel there is an area of stored food known as the (9) _____. The cotyledon of the corn is known as the (10) _____.

Define

hypocotyl **plumule** **scutellum**
testa

CHAPTER XIII

ROOTS FURNISH SUPPORT AND SUPPLY MUCH OF THE RAW MATERIAL FOR FOOD-MAKING

138. Just as we may admire a theatrical performance without thinking of the cost of its production, either in money or in hours of rehearsal, so do we often admire a plant because of its foliage or the color of its blossoms without appreciating the great importance of the unseen feeding and supporting parts in the ground—the roots. That there are many interesting and varied kinds of root systems you would soon discover if you looked at the roots of such plants as the peony or the dahlia and then compared them with those of some orchid or even a dandelion.

139. The Development of Roots.—If you have ever planted seeds and watched closely the developing young plant, you know that when a seed germinates the **primary root,** or first root, develops from the end of the hypocotyl. This primary root continues to grow, other and smaller roots soon developing from its sides, which are known as **secondary roots.** In due time others appear and continue to extend further outward. These are called **tertiary** (*tur'-she-ar-e*) **roots.** From each of these three kinds of roots, when young, very fine hair-like outgrowths of certain epidermal cells appear, known as **root hairs.** Still another type, the **adventitious** (*ad-ven-tish'-us*) **roots,** develop from other parts of the plant—from the stem, as in the willow; or from the leaves, as in a few species such as the begonia.

140. Unusual Places Where Roots Grow.—Although the roots of most plants grow in the ground, certain others live entirely in the air and hence are known as **aërial** (*a-e'-re-al*) **roots.** Familiar examples are the adventitious aërial roots by which an ivy clings to a wall. Numerous tropical plants possess aërial roots

by which they cling to trees and at the same time take in the necessary amount of moisture from the air. Some of the leafless species of tropical orchids depend entirely upon their aërial roots for nourishment as well as for their attachment. Here the roots carry on all the functions usually performed by leaves.

Then there are the **water roots** of some plants such as the duckweed, which you may have seen floating on the surface of some pond. Other aquatic plants possess water roots which serve merely as anchors.

The **parasitic roots** are another interesting type. These are found on such plants as the mistletoe, which gets its food from the trees or other plants on which it grows. The broom-rape and dodder are other species whose root-like structures grow into the tissues of the host (the plant which supports it), and from which it gets its nourishment.

141. The Three Principal Forms of Roots.— Often we find a plant having one main root, usually extending downward and much larger than any of the secondary roots. This is known as the **tap root.** It may be large and fleshy as in the carrot, but it is not necessarily so. Some tap roots are slender, as in the maple.

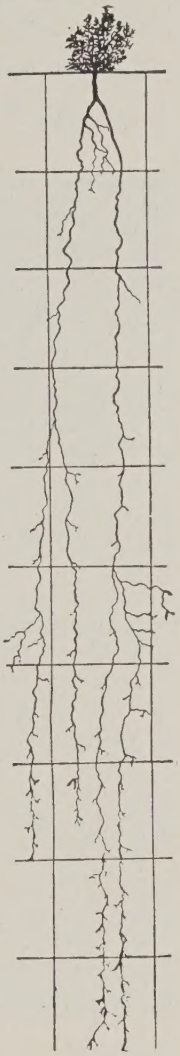


FIG. 73.— The root systems of most annual plants are usually much larger than the part of the plant aboveground. (*After Weaver.*)

Dahlias illustrate a variation in the form of their roots, for instead of having one main root they possess a cluster of **fascicled** (*fas'-ik-eld*) **roots.** These roots are also fleshy since they contain much stored-up food for the next year's plants.

142. A third and common form of root is the **fibrous root.** Here we find a large number of slender, branching roots which spread outward in all directions. Roots of grasses and plantain (a common weed on many lawns) are examples of this. Many weeds which have

fibrous roots are difficult to eradicate because these roots, coming from underground stems, are so well established in the soil.

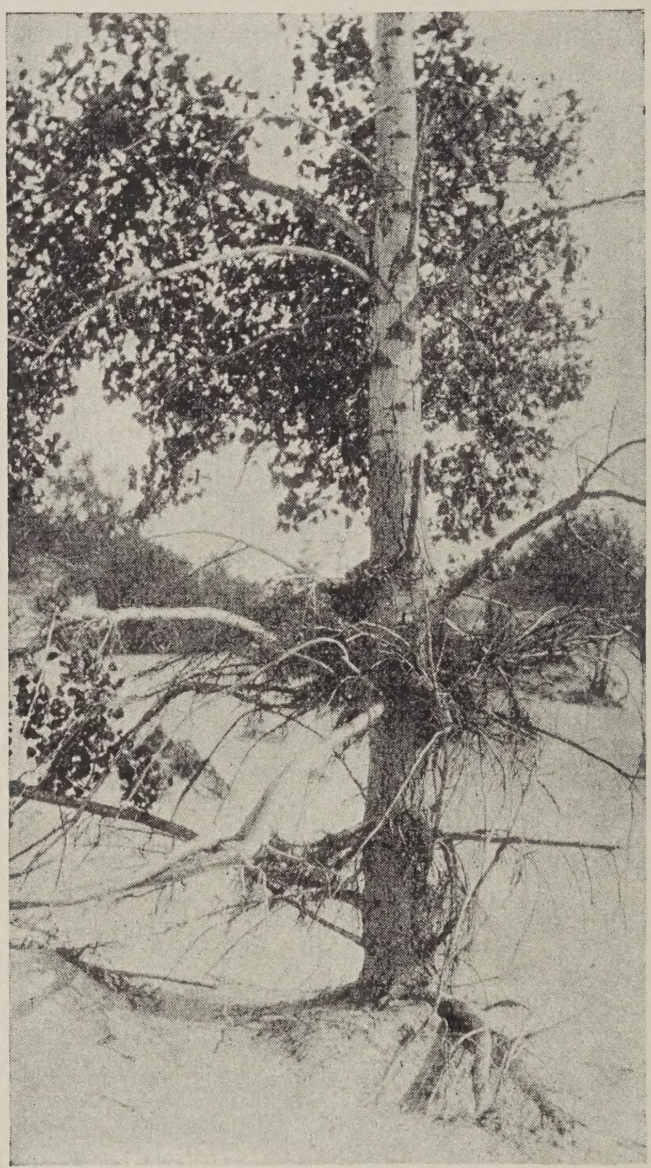


FIG. 74.—Adventitious roots developed from the lower branches while they were covered by sand. Later, when these branches were uncovered, leaves again grew on the branches. (*Courtesy of Mr. Orpheus Moyer Schantz in the National Geographic Magazine.*)

143. Tap roots and fascicled roots also have fibrous rootlets, which serve to provide food rather than support.

144. The Work of Roots.—Except for the algae, fungi, and mosses which have no true roots, most plants are well supplied with roots. Occasionally we find one of the higher plants which has developed in such a way that it can get along without roots. Such a plant is the orchid known as coral-root, in which the root

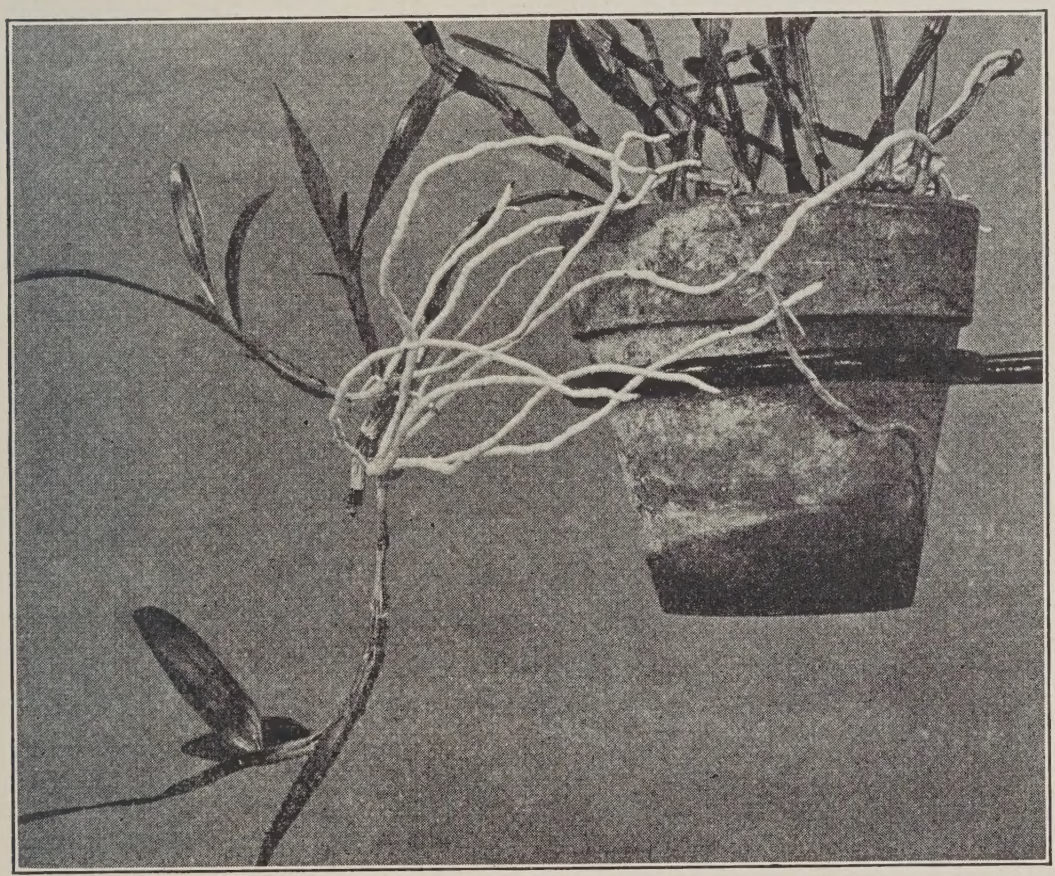


FIG. 75.—The aërial roots of many orchids have several functions; one of which is to absorb moisture from the air. (*Gager.*)

functions are carried on by other parts of the plant. But nearly all of the higher species of plants possess roots which perform three main functions, as follows:

1. They anchor the plant to the ground and in most cases hold it upright.
2. They secure water and certain other raw materials from the soil as food for the plant, since all vital chemical processes take place in water.

3. In many cases they serve as a storage place for the food that has been made by the plant.

145. Root Structure—an Adaptation.—Now let us learn more about the structure of the root. The outer covering, very thin in young roots, is the **epidermis.** Its function is to take in soil water for the plant, and especially to prevent the escape of water which has already entered. Just inside the epidermis is a thick intermediate layer known as the **cortex.** This cortical tissue is made up of several layers of cells somewhat oval in shape. In many roots it serves as a storage place for food. The fleshy roots, such as those of beets, for example, contain large amounts of sugar. In other species this tissue contains large amounts of starch as well as some sugar or proteins, and it may contain all three of these nutrients.

FIG. 76.—Many plants have parasites. In this picture the cactus has been sectioned to expose the parasitic roots. (*Gager.*)

146. Continuing inward through a layer of marginal cells we come to the central cylinder. This is a vascular or conducting tissue, made up of several parts. The woody fibers composed of thick-walled cells together with the bast fibers give strength to the root and aid in the storage of food. The conducting tubes, which are scattered more or less regularly through the outer part of the cylinder, conduct the soil water upward into the stem through the **xylem** (*zi'-lem*) tissue. The **phloem** (*flo'-em*) also serves to carry the sap downward through its sieve tubes to nourish the root and, in the thicker types, to be stored away in the **pith.** The phloem cells lie just outside of the xylem cells, these two layers being more or less separated by the **cambium** layer, which, except at the tip, is the region of growth. If we

follow this central cylinder outward to the end of the root, we can see how the root grows longer; for next to the tip is a densely packed layer of rapidly dividing cells which make up the meristem. At the very tip is the root cap. Composed of dead cells it serves as a protecting cover for the growing root. When a root comes in contact with an obstacle, such as a rock, it curves aside and grows around it.

(Experiment: Line a glass jar with dark colored blotting paper, moisten it, and place some corn seedlings, which have been sprouting in wet sawdust for about a day, between the paper and the glass, you can then see where the root lengthens, on what part of the root system the root hairs develop, and where the root caps are located.)

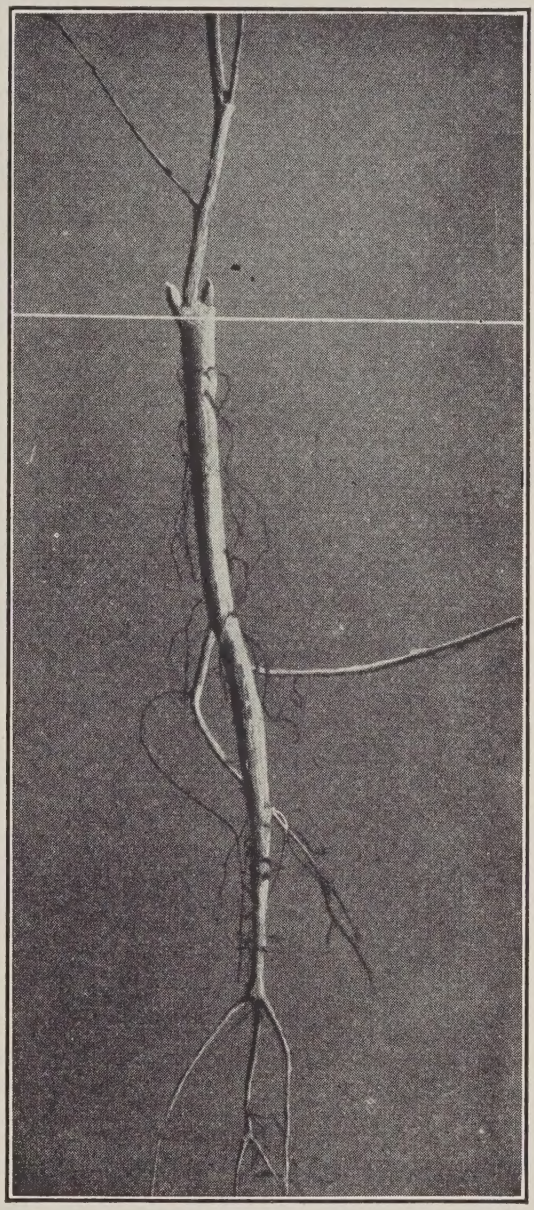


FIG. 77.—In such plants as the sweet clover, dandelion, and carrot, the taproot is the primary root which continues growth straight downward. The white line represents the surface of the ground. (*Atwood.*)

147. Root Hairs.—These structures are so specialized that many persons consider them the most interesting parts of the whole root. Root hairs develop from the epidermal cells of the secondary and the tertiary roots as well as from young primary roots, and are the main feeding cells for the plant. They offer one of the finest illustrations of an adaptation in structure for a special function.

148. Since the root hairs are the feeding cells of the root, it becomes vitally important that their structure be such as to make the inward passage of soil water easy and fairly rapid. Hence the walls of the root hairs are extremely thin for the absorption of water and certain food materials in solution. The very great number of root hairs offers a large absorptive surface.

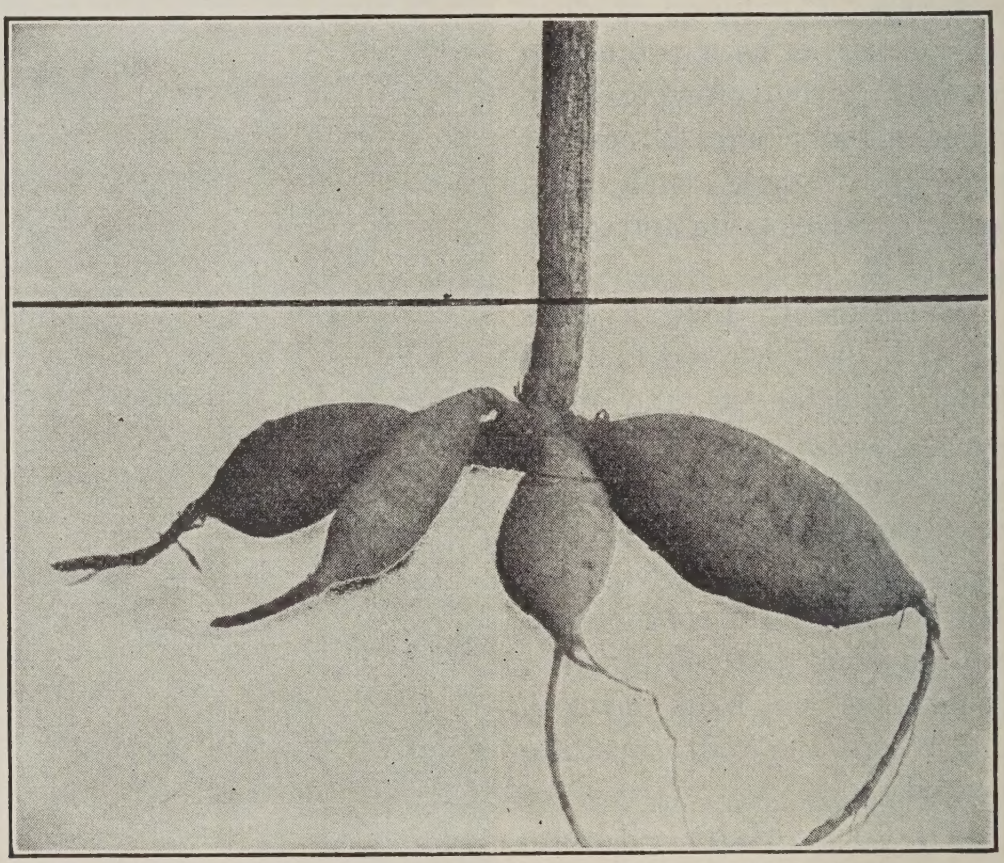


FIG. 78.—The fascicled roots of the dahlia and many other plants are well adapted for the storage of food. (*Mottier.*)

The location of root hairs is favorable, since they are usually close to soil water containing food. By osmosis, large amounts of water and chemical solutions pass through the walls of the root hairs and enter the protoplasm within, the latter being denser than the former. But we must also bear in mind that many chemical salts whose density is greater than that of the protoplasm, also enter the root hairs and so pass into the plant body.

149. We must not think, however, that any substance in the ground will enter the plant just because it may be in solution. Each species of plant has its own characteristics and its own

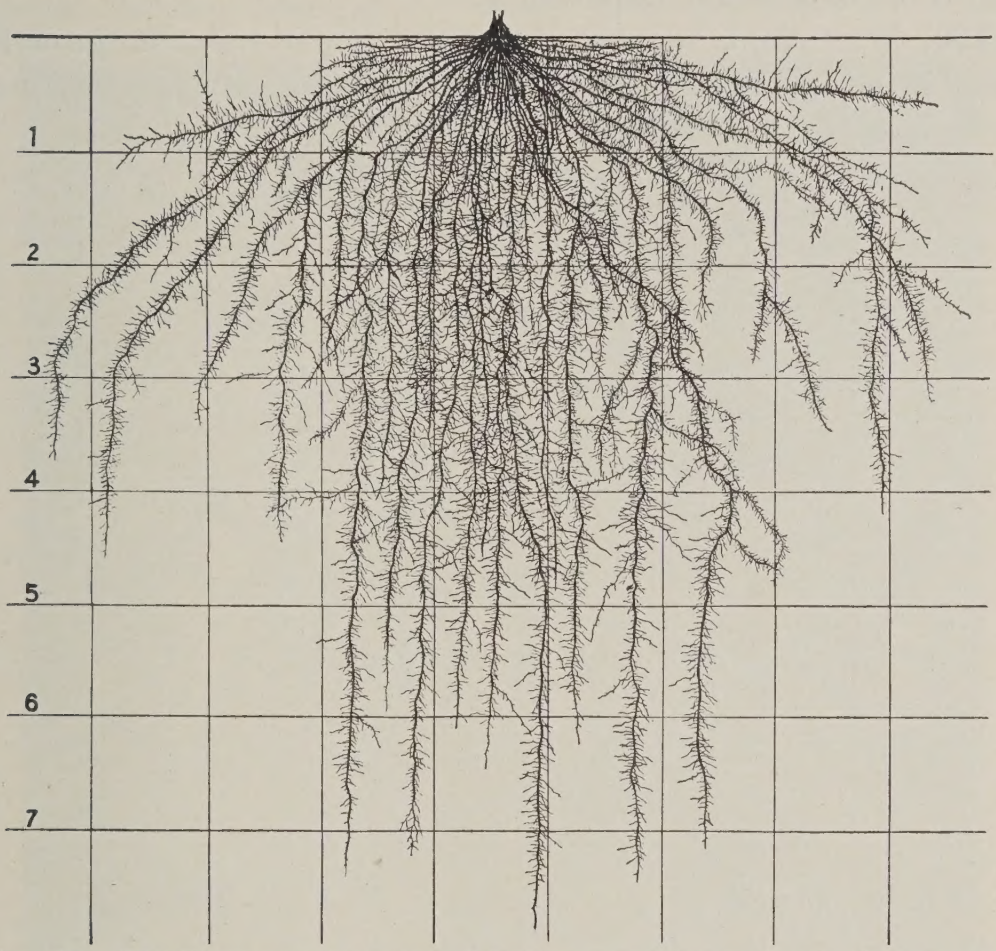


FIG. 79.—The fibrous root system of Indian corn, shown in one-foot squares. (*From Weaver, in Carnegie Institution Pub.* 316.)

chemical make-up. This fact brings us to the process known as **selective absorption.** A corn plant and a rosebush, growing side by side in a garden will not absorb the same chemicals and water in the same proportions. Each of the two plants absorbs that which best suits its need. This fact is recognized by the manufacturers of commercial fertilizers who use different amounts of the various chemicals in preparing fertilizers for the different field and garden crops.

Just how a plant is able to select the water and foods that it needs, and to reject others, is not entirely clear. We know that it is one of the characteristics of the protoplasm of the plant, and is of considerable importance.

150. Most plants require a large quantity of water for growth, since it makes up from fifty to ninety-eight per cent of their

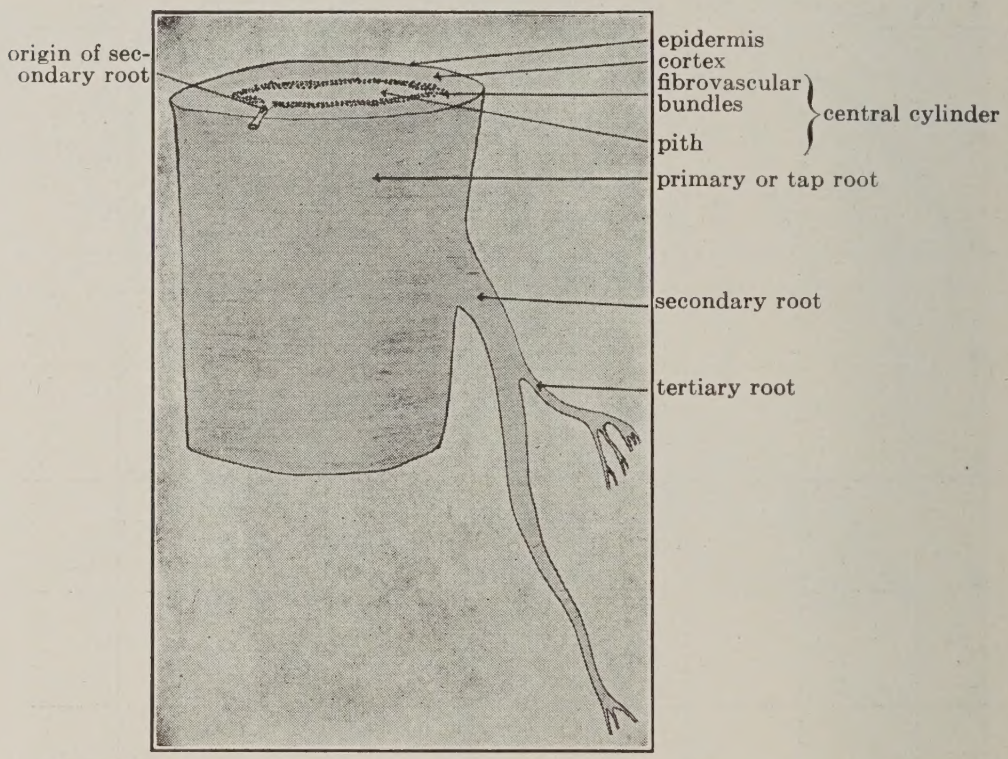


FIG. 80.—Diagram showing external and internal structures of a root.

bodies. It also serves as a medium for carrying materials from the root hairs into, around, and through their bodies. In addition, it serves as a solvent, so that dissolved foods may reach all the tissues of the plant. Hence the work done by the root hairs is a vital necessity to the plant.

151. What Is Soil?—We might well ask "What is the soil in which most plants grow?" Soil, in the beginning, is broken-down and crumbled rock, like sand. But the action of rains and snows, freezing and thawing which has been going on for ages, renders this sand much finer. Then such plants as can

live in this material do so, and after they die the chemical elements of their bodies are returned to the ground. Bacterial action also helps greatly in decomposing the animal and plant matter for their later use.

FIG. 81.—Root hairs are adapted for absorbing soil water with its dissolved minerals. (*Gager.*)

152. What Plants Feed On.—Decayed organic matter, known as **humus,** is the basic source of food for plants. Various chemical salts and water are also present in the soil. Certain parts of these substances become dissolved in the soil water, such substances as the plant needs being thus taken into the roots as food, and carried on into the other parts of the plant.

153. What Governs the Direction of Growth?—It sometimes seems as though roots just grow out in any direction at all. This is not the case. A haphazard wandering might not supply them with enough food to sustain life. Because they are fairly sure of anchorage in nearly any direction, food materials are the determining factors in regulating the direction of growth. After roots get fairly well started, some of them find water and food. This is taken in and stimulates more growth in that direction. One of the reasons why white maples are not planted more extensively for shade trees is that they have a habit of growing into the joints of sewer and water pipes, often causing considerable damage. They grow in the direction where they find food in solution.

154. Failures in Transplanting Shrubs.—Many persons wonder why small trees and shrubs which have been dug up from the woods fail to thrive when transplanted to the lawns about their homes. There are various reasons for this. A good rule to follow when transplanting any wild plant is to imitate its natural surroundings. It grew well there in the woods because that environment was suited for it. The soil contained the necessary elements for its growth. The supply of soil water was suited for that variety of plant. Light and shade conditions were favorable.

155. The writer has seen beautiful maidenhair ferns, which had been growing luxuriantly in the moist shady woods, transplanted to a less favorable environment, where they drooped and in a short time, died. What was the reason? In the new environment the soil contained plenty of decayed leaves and humus. The plants were in the shade nearly all day, but there was one important factor missing—the moisture which they needed. Their new home was on high ground, and the soil had little moisture seeping through it. This condition alone was too much for the ferns to overcome.

156. A person will often dig up a plant without being at all careful about keeping the root system intact, often cutting off one or more of the larger roots. He may also fail to keep the

root system enclosed in the large ball of earth which surrounded it, a protection which any gardener will tell you is very necessary. When the dirt is taken away from the root system, practically all the root hairs which feed the plant, are stripped off with the dirt.

FIG. 82.—A field of sweet potatoes. This is one of our valuable root crops. (*Gager.*)

157. A great many of the so-called "living" Christmas trees, sold in such large quantities, fail to live for this very reason. Their root systems have been mutilated and the heat of the apartments and other homes in which they are placed, lack the moisture that they need. Only too often the roots are allowed to become dry.

It should be remembered that if a successful transplanting is to be made, the requirements mentioned above must be met,

because you cannot disregard the needs of the individual plant.

158. Roots and Agriculture.—The thorough understanding of roots and their requirements must of necessity precede the successful raising of crops. Without well-developed root systems in properly tilled soil which has a good supply of available plant food, crops cannot be successfully raised.

159. Roots constitute an important article of food. Sweet potatoes, carrots, beets, turnips, parsnips and many others are valuable food crops. The common "Irish" potato is not a root but a tuber, an underground stem often incorrectly called a root. Why it is a stem and not a root we shall discover in the next chapter. Certain roots are used as fodder for cattle. Others, such as belladonna and sarsaparilla have a medicinal value. The beet sugar industry depends on the roots of the beets. The economic value of roots in 1933 in the United States alone, according to the U. S. Department of Agriculture, was in excess of $100,000,000.

Interesting Projects

1. Make a collection of as many kinds of roots as you can find and classify them as fibrous, fascicled, tap, etc. Then mount them on heavy cardboard, properly labeled.
2. Plant seeds of barley, corn, wheat, sunflower and any other kinds in a germinating box, or next to the glass of a glass-fronted wooden box of moist earth. Keep in a warm place; add water daily, and watch the differences in the way that the roots of the different species develop.
3. Germinate wheat or barley seeds on a piece of moist blotting paper in a shallow glass dish. Cover the top to prevent them from drying out. Study the mass of fuzzy root hairs which develop as outgrowths of the epidermal layer of the roots.
4. Cut off "slips" from a geranium or an inch plant. Keep these in water for several days and see if you can produce new plants by means of the adventitious roots which will develop. After these roots are well developed, transfer your plant to a flower pot filled with rich earth.

Review

1. What are the principal functions of roots?
2. How is their structure adapted to perform each of these functions?

3. How do roots obtain certain materials for making food?
4. Why do most roots need humus?
5. Name the roots of a tree in the order in which they develop.
6. Why do we often encounter failure in transplanting shrubs and other plants which we have brought home from the woods?
7. Make a list of ten kinds of roots which you consider most valuable to us as food.

Define

adventitious root
aërial root
cambium
cortex
fascicled root
fibrous root
humus
parasitic root
phloem
primary root
root hair
secondary root
selective absorption
tap root
tertiary root
water root
xylem

CHAPTER XIV

STEMS, AS AVENUES FOR DISTRIBUTION, HELP TO MAKE THE PLANT A UNIT

160. In the Redwood forests of California is a tree before which thousands of persons have stood and marveled. They have been awed by the size of its mighty trunk, more than thirty-six feet through (diameter) and reaching two hundred and eighty feet into the air. Like any other monarch it stands, towering above its fellows, serene in its majesty. Many people have wondered about its history, for it is older than all the less ancient countries and civilizations of the earth. Today it is more than four thousand years old. It was a giant when Christ was born. Its branches were raised aloft by that mighty trunk when Moses led the Children of Israel out of Egypt. In its old age it looked down upon the discovery of America, and it is still alive today. If you will look at its picture in the frontispiece you, too, will admire it.

161. The Functions of Stems.—We speak of the central part of a tree as its trunk, but in smaller plants this part is known as the stem.

The most noticeable work of stems, like the trunk of the sequoia tree mentioned above, is to support the branches and leaves. The latter are the plant's food factory and must reach up into the sunlight.

162. A second function of stems is the transportation of water and food. Without a doubt water is the most important single substance taken in by a plant, and it is found throughout the entire body of the plant. After the plant's food is produced in the leaves it must be transported to the other parts of the plant where it is needed for growth, for repairing injuries, for liberating

energy, and for building material out of which come buds, flowers, and fruits.

163. Still another function of stems is the storage of any food and water that may not be needed immediately by the plant. The very large size of the stems of many plants, such

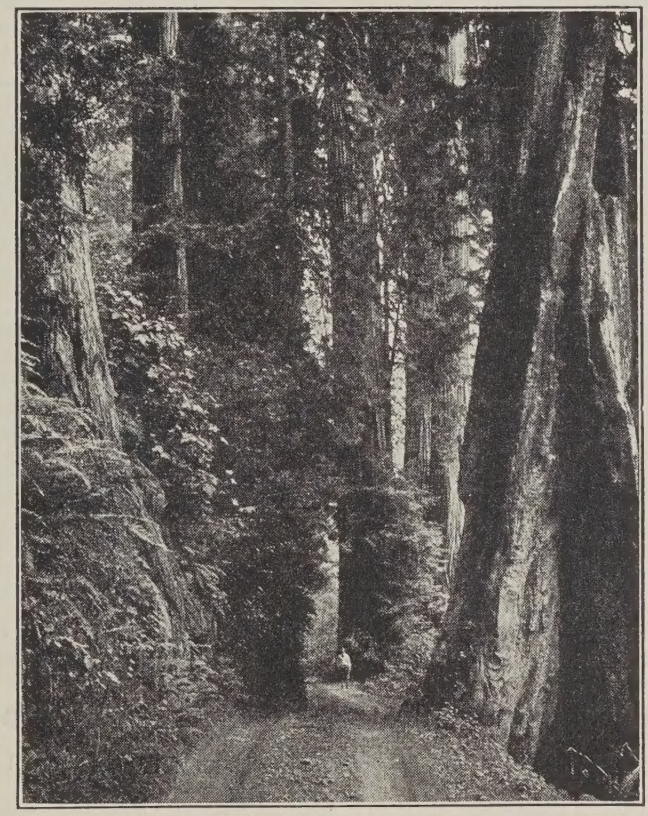


FIG. 83.—These giant redwoods are beautiful examples of erect stems. (*Courtesy, American Forests, the magazine of the American Forestry Association.*)

as those of the cactus, shows us by their very size that some food and a considerable amount of water are stored in these stems.

164. Types of Stems.—The commonest type of stem is the **erect stem.** This is found in nearly all trees. They stand upright like the maple, the elm, and the hemlock. Many of the smaller plants also have this type. Another type of stem is the **reclining stem,** such as the "runners" of the strawberry plant. These stems creep along the ground and, after growing a few inches, develop roots and so form a new plant. The

"runners" continue to creep on, often forming a chain of plants. Blackberry and raspberry plants are also familiar examples. Here the **stolons** lean over, many of them touching the ground, where they develop roots which form new plants. Often farmers increase the size of their blackberry "patches" by bending the stems over and then weighting them down with shovelfuls of earth to form new plants.

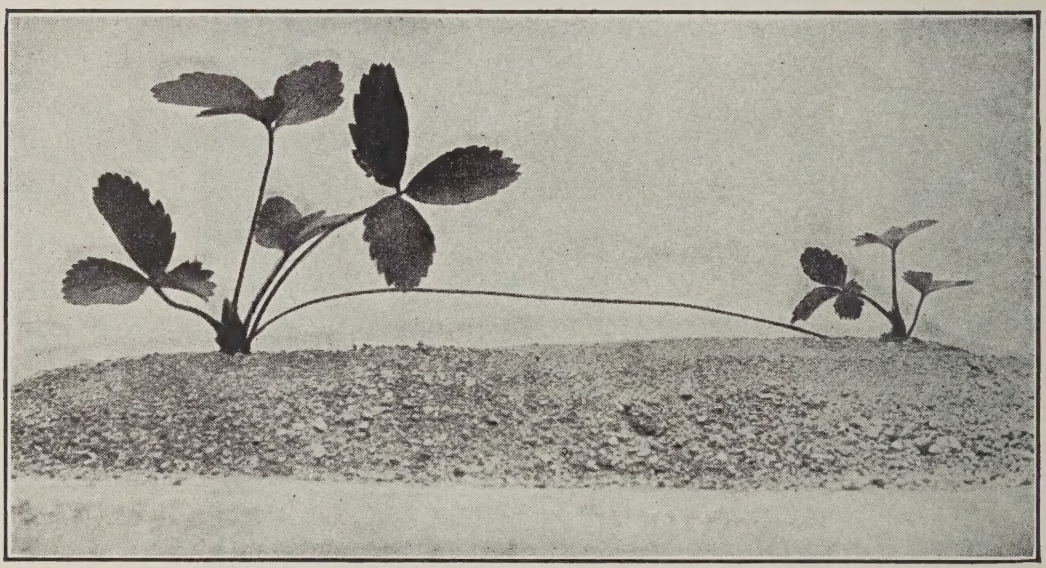


FIG. 84.—The strawberry plant reproduces by means of stolons. (*Atwood.*)

165. But perhaps the most peculiar are the **climbing stems.** Plants have various devices for climbing up into the sunlight. In the tropical regions where the vegetation is so dense that the sunlight rarely reaches the ground, we find the greatest development of the climbing stems. The smaller plants that grow here must reach up into the sunlight in order to live, and we find them doing it by means of tendrils or by adhesive disks (which may be modified leaves), by stipules, by stems, or even by aërial roots (See Chapter X). As the tendrils grow upward, their tips move slowly around in a more or less circular path until they find some support. Then, after taking a few turns around it, they begin to draw the stem upward by becoming shorter themselves as they form the numerous spirals that you have seen among sweet peas and pumpkins. Thus we find these interesting climbers right in our own gardens.

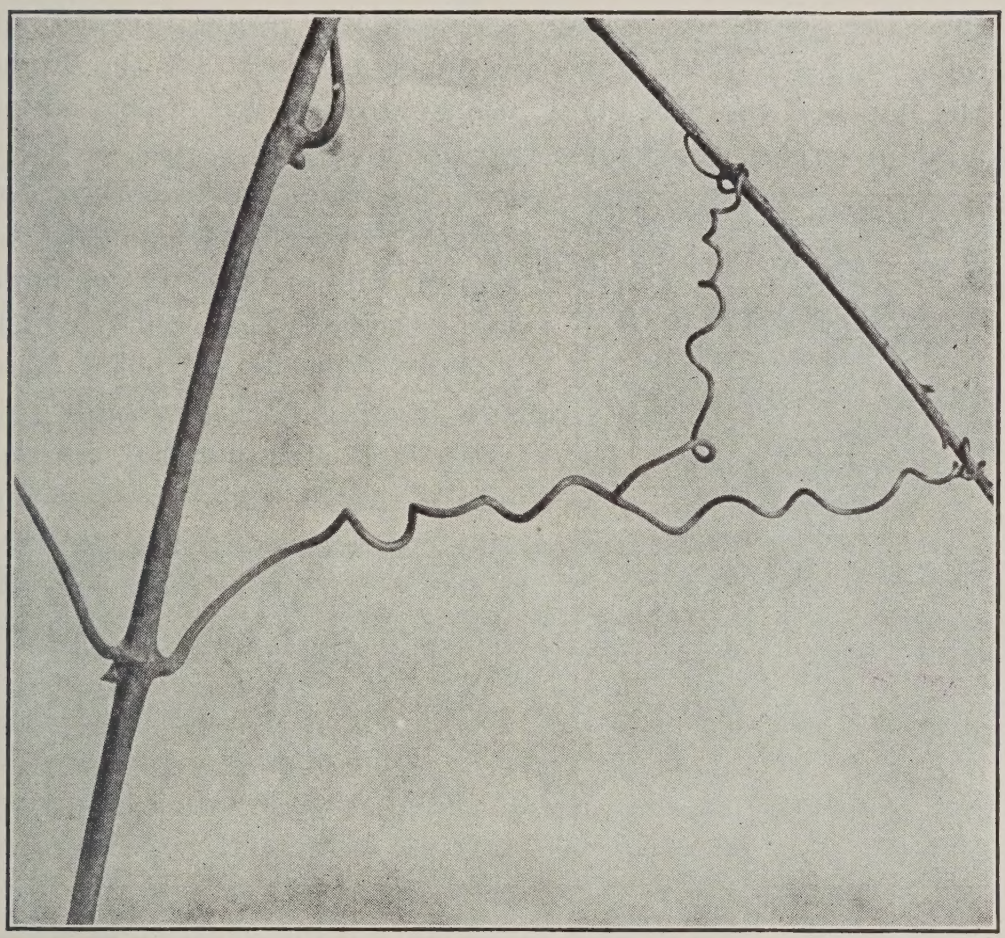


FIG. 85.—The grape vine pulls itself upward and clings to its support by means of its climbing stem. (*Atwood.*)

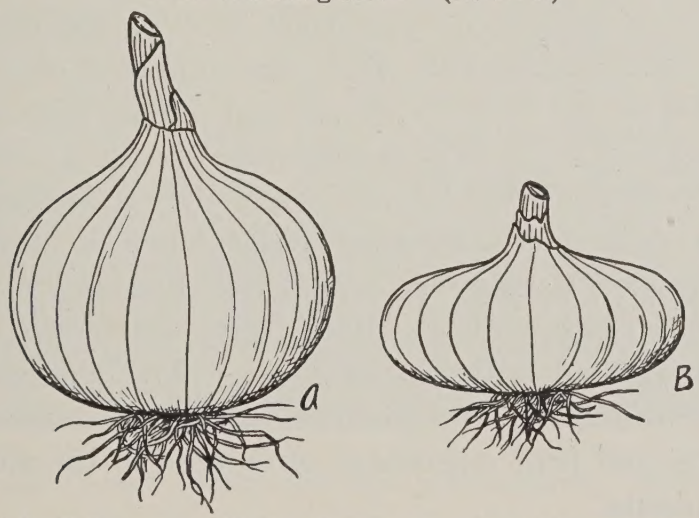


FIG. 86.—A bulb is composed of a short stem on which are fleshy, overlapping leaves quite rich in food material. There is a terminal bud, and occasionally lateral buds are present. These develop into new plants. (*Robbins.*)

166. The stems of certain other plants grow upward by twining themselves around other objects. Such are the stems of the hop and the wax plant, whose growing tips sweep slowly around in circles, sometimes two or three feet across, as they search for higher supports. No doubt you recall the tendrils of the grape vine. Possibly you have noticed the twining stems by which the several species of "pole" bean plants in our gardens grow upward. If you will examine the various kinds of weeds that are growing around the edges of many gardens, you will not have long to look before finding still other climbing stems.

FIG. 87.—The corm of the cyclamen, like any other corm, is a short, solid underground stem covered by a few scale-like leaves. (*Atwood.*)

167. Perhaps you have thought of the dandelion as a plant without a stem, since its stem is so very short. It well illustrates the **crown stems.** Here the leaves arise from an imperceptibly short stem at the crown of the plant. **Bulbs** are another kind of specialized stem. They are composed of a very short shoot and stem, covered with a great many thick, over-lapping leaves which serve as storage spaces filled with food for the young plant when it develops, the following year. **Corms** are somewhat like bulbs only that they are relatively leafless. Here again, their size is due to their being packed with stored food. The Jack-in-the-Pulpit reproduces principally from corms, although the seeds formed in their large red fruit clusters so often seen in the autumn, also form new plants.

168. Rootstocks are another type of specialized stems for they are underground stems. Many plants reproduce and form

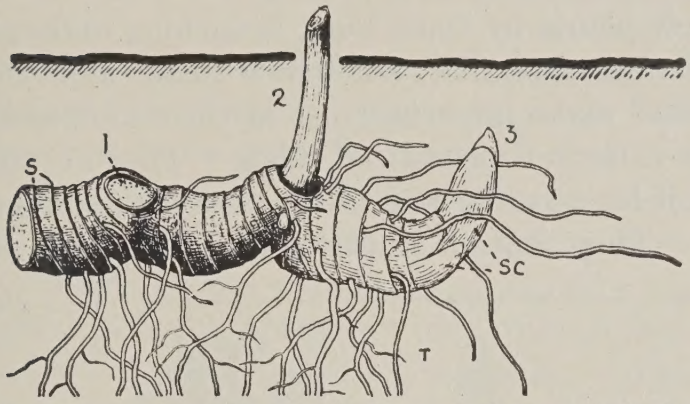


FIG. 88.—Many plants including the well known Solomon's Seal rise from these rootstocks which are underground stems. 1. Scar of last year's aërial shoot; 2. Base of this year's shoot. 3. Terminal bud of next year's shoot. *S.C.* Scale leaves. *S.* Scars of old scales. *r.* Adventitious roots. (*Gager.*)

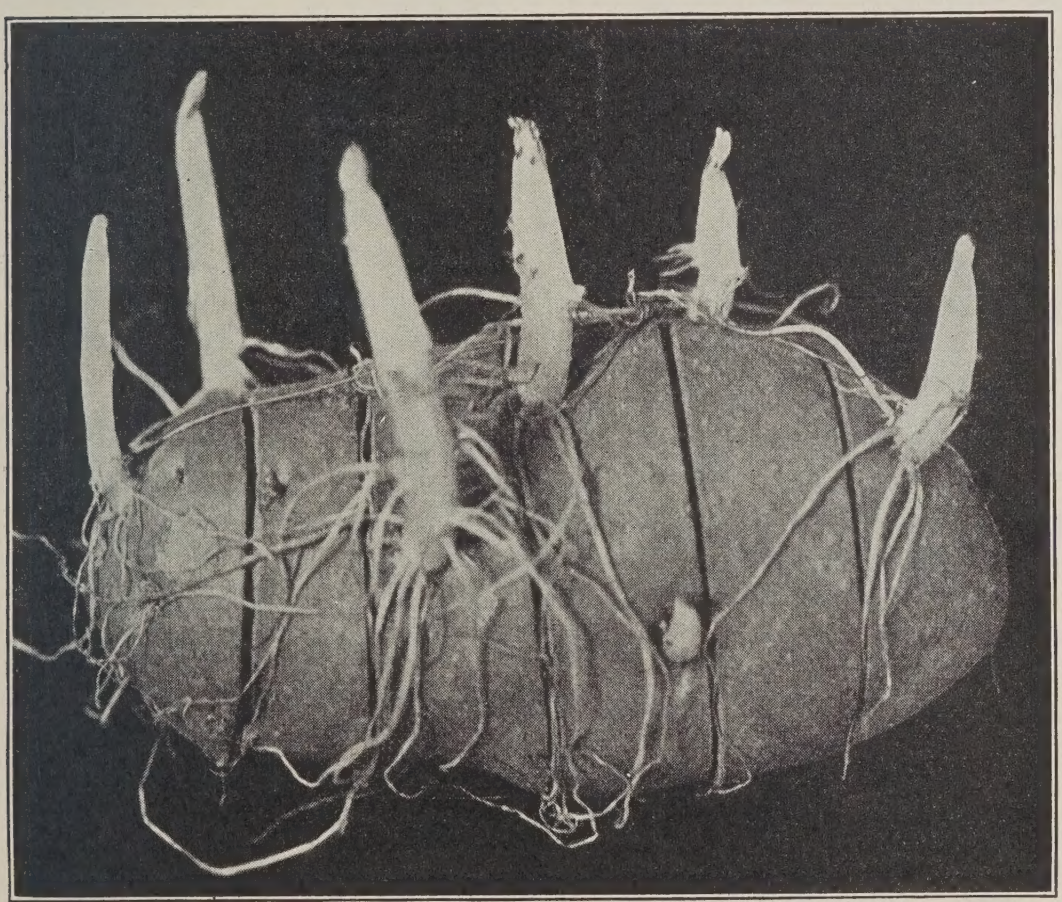


FIG. 89.—The common white potato is a tuber. When the pieces are planted, the buds, called "eyes," develop into new potato plants. (*From Gager, after Appleman.*)

a line of new plants by these long, branching underground rootstocks. The sarsaparilla, Solomon's seal, and the common "witch grass" make important use of their rootstocks. **Tubers** are another variety of specialized stems. They are tremendously important, if for no other reason than that our common potatoes are tubers. They contain much food for the young plants which

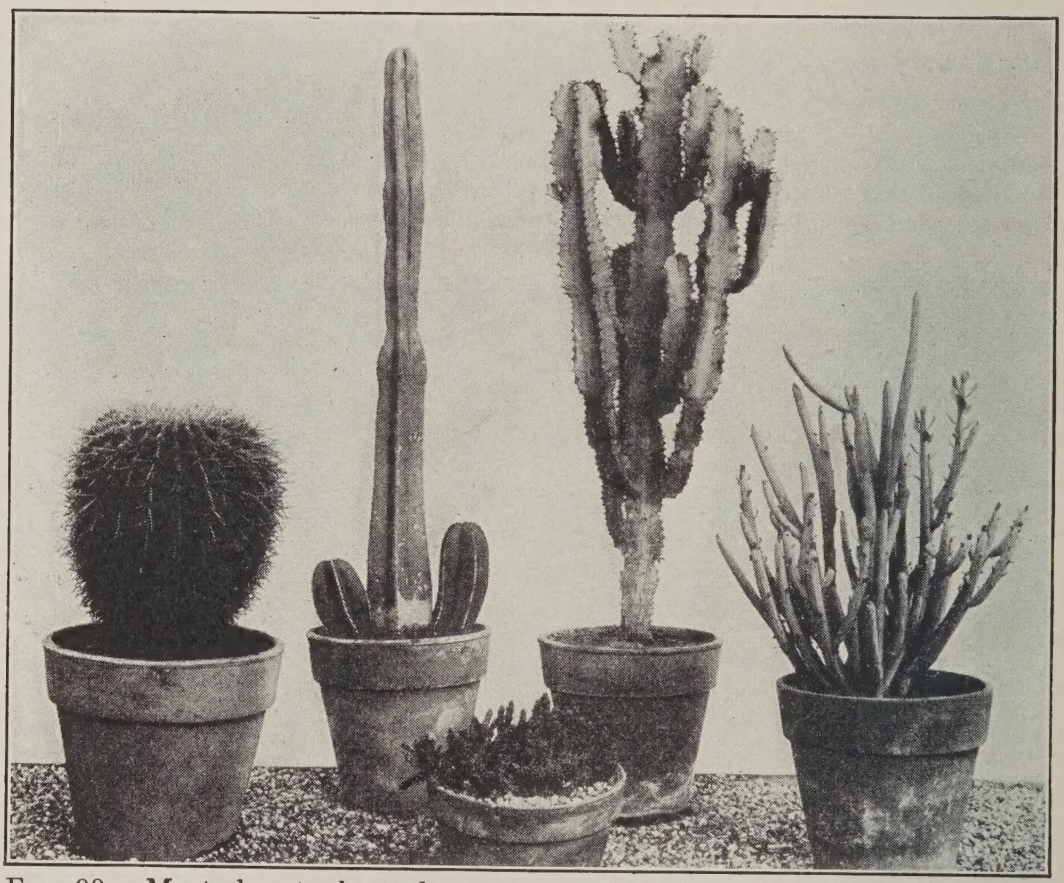


FIG. 90.—Most desert plants have stems adapted for the storage of water. (*Gager.*)

develop from the "eyes" the following year. This food, produced in the leaves, is transported down through the underground stems to the tubers. The "eye," where growth starts, is really a bud.

169. "Succulent" means "containing a large amount of water"; the **succulent stems** are therefore well named. In the case of certain desert or semi-arid forms, including cacti, these

stems present a unique method of providing against drying out. Their characteristic property is that they are fleshy and show great ability to store up water for the plant at all times, especially when the supply is scarce. The **liveforever** is one such plant; it is difficult to eradicate because of its ability to store up water and put forth new shoots after being apparently killed.

170. Buds.—A bud is always an undeveloped branch. It may or may not have a protective covering of scales. The buds formed during the summer show us that the plant is always getting ready for the next year's growth. Buds may have either of two positions, depending upon their location. They are either **terminal** (at the tips of branches), or **lateral** (developing from the sides of either the branches or the main stem). Buds are classified according to the part of the branch formed. Leaf buds contain the rudiments of leaves; flower buds likewise will form flowers, and mixed buds produce both flowers and leaves. These can often be distinguished by their size; leaf buds are usually more slender, while flower buds are generally stouter and rounder. Since buds must live through the long, cold winter, they must be protected in order to avoid the loss of their water by transpiration, and to prevent freezing and thawing which are in themselves drying processes. The tightly overlapping scales of most species are quite effective in giving this protection while a few species are lined with either hairs or a woolly substance which serves more or less as a non-conductor of heat and thus aids in retaining the water as well as giving general protection.

171. Structure of Stems.—The stem of the plant is well fitted to carry on its three main functions. These are to support the branches and leaves, to transport fluids to the different parts of the plant, and to act as a storehouse for food. Some other functions are carried on in a lesser degree, such as digestion and respiration.

172. The two main groups of flowering plants are the **monocotyledons** and the **dicotyledons.**[1] These two terms describe

[1] The cycads and conifers comprise the group known as polycotyledonous plants, since their seeds have more than two cotyledons.

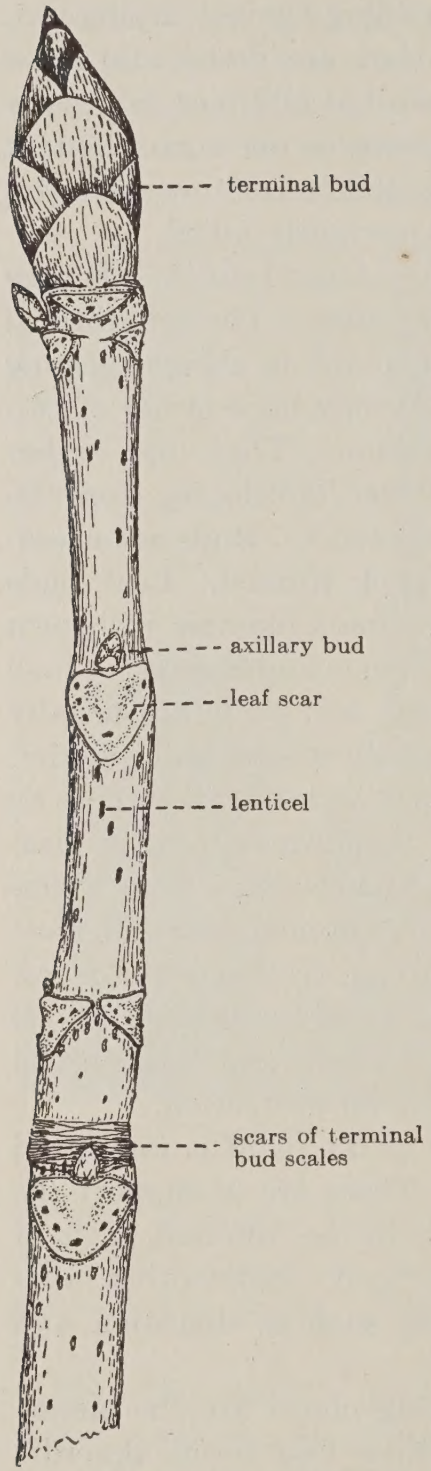


FIG. 91.—A horse-chestnut branch. (*Mottier.*)

the embryo of the plant as to the number of its cotyledons. Some of the more familiar monocotyledonous plants are the grasses, corn, bamboo, lilies, and palms. For our examples of dicotyledons perhaps the pea, bean, peanut, and most of the deciduous trees are as well known as any others. Each of these divisions of the plant kingdom differs from the others in the number ot the cotyledons, the kind of leaves which it possesses, and the structure of its stems.

173. *Dicotyledonous Stem, External Structure.*—If you examine any one of the end twigs from some tree that grows near your home, you will be making an excellent beginning of the study of stems, for you will notice several very definite structures. Probably you will first notice that the last few inches of the twig are of a lighter brown color than the area farther back. Often these new twigs are shiny and are more smooth. Now follow this twig back to the point where its growth started. This point is easily distinguished by a darker colored ring, the **bud scale scar.** The young, fresh growth was made this last season as one would expect, for the ring of the bud scale scar marks the place where the terminal bud was located a year ago. You can also tell by the **leaf scars** where last year's leaves were located. Above

each leaf scar is a bud. Some of these buds will develop into branches next year, as did those further back last year. Notice also the tiny "windows" or **lenticels** (*len'-te-selz*). These are the breathing pores of the stem. At the tip of the twig is a very conspicuous **terminal bud,** larger than the **lateral buds** mentioned above.

174. *Dicotyledonous Stem, Internal Structure.*—Cut a similar section of young castor bean stem. The outermost layer shows the characteristic color, is very thin, and is known as the **epidermis.** Just inside this is the **cortex.** In young trees this is green; in older trees it is often brownish. In either case it is much thicker than the epidermis. Just inside the cortical tissue we find the **cambium layer,** the area where growth takes place. Arranged at close intervals on this cambium ring are the numerous vascular bundles. The center of the stem is composed of the **pith,** extending outward from which are the silver-colored **rays**[1] which offer a passage from the cambium layer to the pith or storage area.

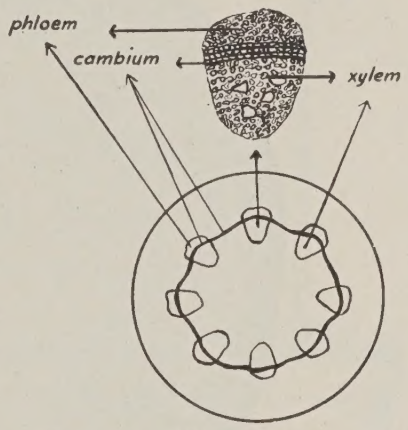


FIG. 92.—Diagram showing cross section of a dicotyledonous stem.

175. *The Monocotyledonous Stem.*—If you will cut some thin slices from a corn stalk, cutting straight across, you will notice that the outside is made up of a very hard **rind.** This serves for protection and for supporting the stem. The whole inner portion consists of a light-colored, soft material called **pith,** through which are scattered rather regularly numerous roundish structures resembling dots. These are the **vascular bundles,** which serve as a series of connecting tubes for transporting the soil water up to the leaves and for carrying the sap downward to nourish the whole plant.

[1] These may be either pith rays or vascular rays, according to the kind of plant.

176. From our study of these two types of stems, we can now make certain comparisons. We find, first, the outer part of the dicotyledonous stem to consist of a thick bark, whereas the outer part of the monocotyledonous stem is made up of a rind which is thinner but much harder. At certain places along the monocotyledonous stem we find nodes or joints from which the leaves grow. Secondly, in the dicotyledonous stem we find the vascular bundles arranged in a definite circle, whereas in the mono-

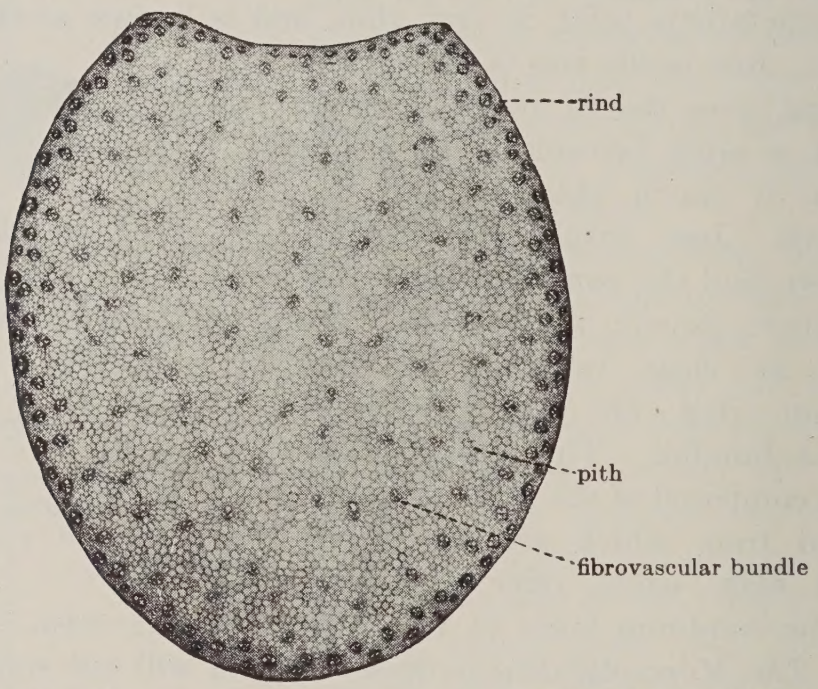


FIG. 93.—Cross section of a young stem of Indian Corn. (*Mottier.*)

cotyledonous stem they are scattered irregularly throughout the pith. Thirdly, in the dicotyledonous stem the pith occupies a relatively small place in the center of the stem, with its rays radiating outward, whereas in the monocotyledonous stem the pith occupies a large part of the space within the rind.

177. The Functions of the Various Stem Tissues.—The principal function of **epidermis** is to prevent too rapid loss of water by transpiration. The epidermis also protects the inner tissues of the stem against wind and rain, the spores of plant parasites, and probably the attacks of the smaller insects. The several tiny openings in the stem, known as **lenticels,** admit air

to the cortical tissue thus supplying it with oxygen and carbon dioxide for making food. A limited amount of transpiration also takes place through these lenticels.

178. The **cortex** also protects the tissues within and incidentally aids in the process of food production, supplementing the work of photosynthesis which is carried on in the leaves. The green chlorophyll in this tissue is easily seen in young stems.

Vascular tissue makes up the conducting system by which the soil water from the ground is brought upward into the leaves through the xylem cells which make up the inner portion of the vascular bundle.

179. In the taller trees a great amount of energy is required to lift the large amount of necessary soil water up to the leaves where it is to be used. At least three factors contribute to this work of overcoming gravity. One of these is **root pressure.** Root pressure depends on osmosis or, rather, on **successive osmosis,** for in this way the soil water is passed on from the root hairs which first receive it, up into the plant. This soil water, which is less dense than the protoplasm within the root hairs, enters readily, for you remember that the general direction of flow is from the less dense to the denser medium. Now as the soil water enters the protoplasm, the protoplasm becomes less dense than that of the next tissue beyond. Hence the soil water flows on and on, always from the diluted (less dense) cells to the denser ones just beyond. It passes from the cortex of the root to the tracheary tissue of the vascular bundles. The cells of this tissue are adapted for the easy passage of liquids through them since they are much elongated and their ends consist of very thin membranes.

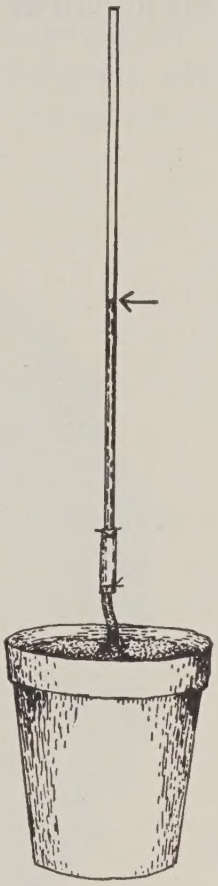


FIG. 94.—When a glass tube was substituted for the stem of the plant, soil water rose some distance in the tube because of osmotic pressure. (*Mottier.*)

180. All these forces however, are not sufficient to explain the ability of a tree like a giant sequoia (*se-kwoi'-ah*) of California to lift hundreds of gallons of soil water every day to a height of two

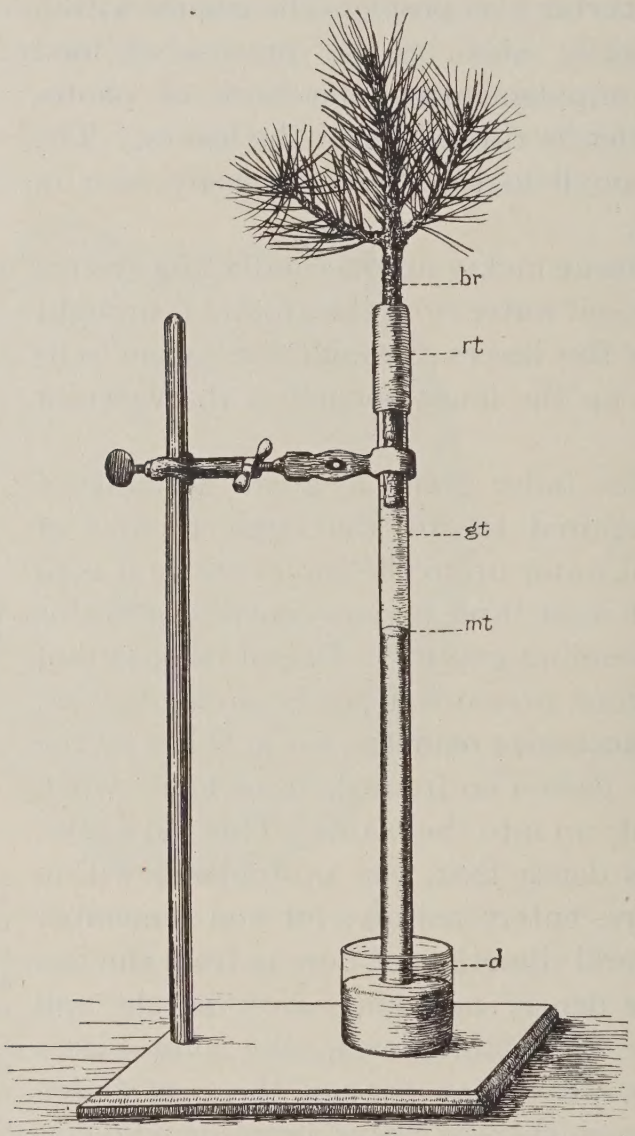


FIG. 95.—Experiment to demonstrate the so-called "lifting power" of transpiration. *d*, dish of mercury; *mt*, top of mercury column that has risen in the glass tube, *gt*; *rt*, rubber tube; *br*, branch of a pine tree whose leaves are transpiring. (*Gager.*)

hundred feet or more. How this is done is just another of those mysteries of nature which have not been entirely explained as yet. Transpiration in the leaves brings about a pull, by pro-

ducing a partial vacuum. Hence a very tiny column of water **in contact with the wet walls** of a tube, has sufficient tensile strength to be drawn up without breaking the column.

All the forces, together, insure the leaves an adequate supply of soil water—the building material out of which, together with carbon dioxide from the air, nutrients are made in the leaves.

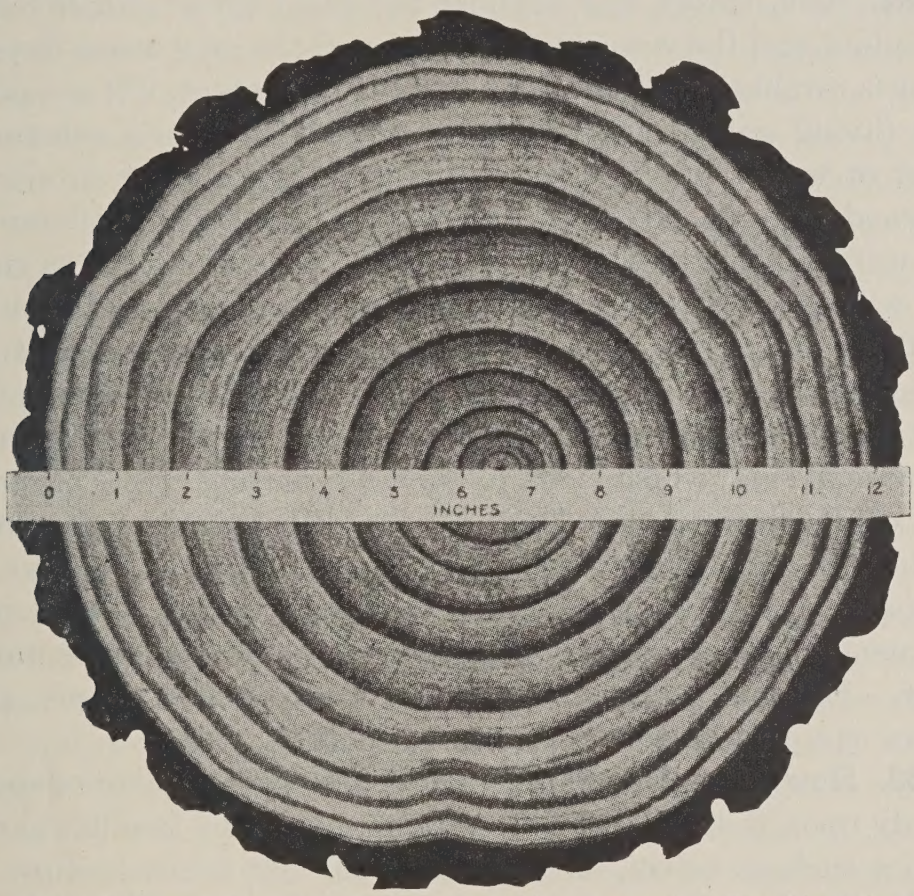


FIG. 96.—Cross section of a twelve year old tree trunk. The black irregular outer area is the bark. The darker bands indicate the summer wood of each annual ring. The lighter zones are the spring wood. (*American Forests.*)

181. This food has to pass downward through the sieve tubes and plates, to nourish the various parts of the plant. These sieve tubes and plates, which are composed of somewhat elongated cells with very thin perforated ends make up the phloem tissue. This tissue is the area of the downward flow of sap, and makes up the greater part of the vascular tissue. Growth develops

from the cambium, which is a cylindrical-shaped thin layer of cells. From this layer new wood cells are formed on the inner surface and phloem cells on the outer surface. Vascular rays are formed on both surfaces. Hence it is easy to understand that the cambium is the region where all the growth in thickness takes place—where the building material is supplied.

182. Each spring and summer the plant grows, for if food is abundant and the water supply is normal the long warm days are most favorable to growth. Each season the plant, if it is a perennial (living several years) like the trees, builds on a substantial layer of wood. As the season progresses, a greater proportion of wood fibers is produced and less tracheary tissue; hence the cell walls become thicker and denser. Then when autumn comes and winter, with a decreased supply of sunshine and warmth and available food, this growth stops. The densely packed layers stand out in striking contrast to the loosely packed layers of the next year's growth and a distinct ring can be seen. This ring, the **annual ring,** which is made up of alternating layers of porous and compact wood, is caused by the different rates of growth of the wood at different seasons of the same year. Because one such annual ring is formed every year, it is possible to determine the age of a tree by merely counting the number of these annual rings. Especially in young plants, the innermost tissue, pith, serves as a region for the storage of food.

183. How Long Do Plants Live?—The age of plants depends largely upon their method of reproduction. The familiar garden species such as asters, sweet peas, corn, and beans mature and produce their seeds one year to form the plants of the next year. Such plants are called **annuals,** since they live but one year or less. Others—such as beets, carrots, and cabbages—require parts of two years for the formation and ripening of their seeds and so are known as **biennials.** The other plants, including the trees and shrubs, live for more than two years, usually a great many, and so are termed **perennials.**

184. Artificial Methods of Propagating Stems.—In recent years plant growers and horticulturalists have become so proficient in the raising and breeding of plants that today it is possible

to produce varieties having many shapes and characteristics wholly unknown a few decades ago. Luther Burbank, often called "The Plant Wizard," has probably done more in the way of producing new varieties than has any other man. What were some of the unusual varieties that he brought forth?

185. *Grafting.*—It is possible to utilize an otherwise worthless wild or "scrub" apple, pear, peach or plum tree, whose fruit is tasteless or sour, by grafting on to it a small branch two or three inches long called a **scion** (*si'-un*), from some desirable tree of the same family. This is done in a number of ways, one of which is **cleft grafting.** This is accomplished by cutting off a branch one-half to two inches in diameter, splitting it down an inch or two through the middle, and inserting the scion with its two or three buds. The scion must be inserted so that the cambium layers of the stock (the tree) and the scion come together. Then the cut area is covered over with grafting wax to keep it moist by preventing evaporation. The sap from the stock will then flow into the scion and produce a branch which will bear fruit of the desired variety. Such grafting is usually done in early spring before the sap begins to flow freely. **Whip grafting** is another method similar to the above, except that the cuts are made in a slanting direction. This method is used on smaller stems and branches. **Budding** is still another method, used to a great extent in nurseries, for grafting young peach trees, rose bushes, and a number of other plants. A T-shaped slit is made in the bark of the plant and a little slab of bark having a bud, is slipped in just under the cortex. The bark is then bound up to hold the bud tightly in place until it begins to grow. Branches of the same or of other species may be used in all grafting, as long as they belong to the same or closely related kinds. For instance, pears have been successfully grafted onto apple trees by these methods. **Layering,** still another method of artificial propagation, has already been mentioned in connection with reclining stems, on page 114.

186. Girdling.—Before the white man came to America, the Indians used this method of killing trees to clear the land.

It consists of cutting a groove entirely around the tree at any convenient height, deep enough to penetrate the cambium ring. The normal flow of soil water to the leaves is thus prevented when the xylem tissue is penetrated. Since no soil water can rise above the cut the leaves begin to wilt almost immediately, and the tree dies within a relatively short time.

FIG. 97.—No tree can withstand the effects of girdling. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

187. Pruning.—The beauty of shade trees depends to a great extent on their being symmetrical, with branches rather evenly placed on all sides. The success of ripening fruit on fruit trees is much greater if the central part of the tree is not filled up with a mass of small branches which keep out the sun. After deciding what shape the tree should properly have, one can obtain it by neatly cutting off the unwanted branches, close to the trunk or to the larger branches from which they spring. Extremely long branches are likely to get broken off by winds or by weight of snow, besides making an ill-proportioned tree. Careful pruning often prevents the disfigurement of beautiful and

valuable trees. In all cases where a cut surface is exposed to the weather, this cut should be painted over to prevent decay and the entrance of parasites.

188. Economic Importance of Stems.—Stems are extremely important because they supply man with so many necessary products. In many parts of the world wood from the trunks of

FIG. 98.—Field of corn. (*Courtesy of International Harvester Co.*)

trees is the main fuel. To a great extent our homes are made of wood, although substitutes are being used more and more every year because of the high cost of timber for building.

189. Many medicines and other products such as turpentine, rubber and maple sugar come from the trunks of trees. All our linen cloth is made from the stems of the flax plant. Much of our food, such as cane sugar, potatoes, celery, and asparagus also comes from stems. There are also other and different uses of stems, such as for furniture, boxes, general construction work, and paper. Thus we see that the stems of plants are of great economic importance to man.

Interesting Projects

1. Mount on a sheet of bristol board several kinds of erect stems, reclining stems and climbing stems. Label each species, and note any adaptations for carrying on its particular work.

2. Observe such climbing stems as those of sweet peas, or common garden peas, and make drawings on several successive days showing the position of two or three stems at different times. What effect do you observe when the tip of the stem touches any support?
3. Select some low branch of a bush or tree near your home, and make a series of drawings or better, photographs, of this same branch taken from the same spot in (a) winter, (b) early spring when the buds begin to swell, (c) a few days later, and (d) later still when the buds burst into flowers or leaves.
4. Find some shoots of the common "witch grass" breaking the ground in the garden. Then dig up the earth around this shoot, and examine the rootstocks from which these new plants have sprung. Are there other shoots developing at the swellings or nodes? Is there a terminal bud?
5. Cut a limb from some tree, or examine the stump of a tree that has been cut down. Can you tell the age of the tree by the number of annual rings?

Review

1. What are the principal functions of the stem?
2. How many types of stems are mentioned in this chapter? Which of these types have you ever seen?
3. Is the common potato a stem or a root? Give one reason for your answer.
4. Name, and tell the function of each of four different kinds of specialized stems.
5. In what ways are many buds adapted to withstand the coldness of winter?
6. What differences of structure are seen in cross sections of monocotyledonous and dicotyledonous stems?
7. What type of grafting would you use on (a) an apple tree, (b) a rose bush?

Define

adhesive disks
annual ring
biennial
bud scale scar
bulb
cleft grafting
climbing stem
corm
crown stem
erect stem
flower bud
girdling
lateral bud
layering
leaf bud
leaf scar
lenticel
perennial
pith
pruning
reclining stem
rind
rootstock
scion
stolon
succulent stem
terminal bud
tuber
vascular bundle

UNIT IV

ANIMALS SHOW MANY RELATIONSHIPS, WHEN ARRANGED ACCORDING TO COMPLEXITY OF STRUCTURE

CHAPTER XV

PROTOZOA ARE ONE-CELLED ANIMALS

190. In every brook and stream, in every river, pond, and ocean you can find **protozoa** (*pro-to-zo'-ah*). They are the simplest yet perhaps the most widely distributed forms of all animal life. Their very simplicity seems marvelous when you learn that they can carry on all the functions that the higher animals perform. They seem to have their own ways of breathing, eating, moving, and carrying on the other life processes, and they are such unusual creatures that after you have seen through the compound microscope your first protozoan, you will want to see others and to know more about this interesting group of animals.

191. Protos is an old Greek word meaning **first. Zoa** means **animals.** They are the smallest animals in the world. Some of them, such as the amœba, are unique in having no fixed shape and often change their shape a dozen times within as many minutes. They are surely first when it comes to structure, for theirs is the very simplest. And lastly, nearly all zoölogists (*zo-ol'-o-jists*) believe that the first forms of animal life on the earth were very simple microscopic forms; so the protozoa were probably the first animals to appear on the earth.

192. The Amœba.—So much has been written and said about the amœba (*am-e'-bah*) that we may well begin with this form of

life. Some one has said that when we are watching an amœba under the compound microscope, we are studying the behavior of protoplasm, for what is an amœba, after all, but a tiny mass of protoplasm? Protoplasm, you remember, is the only substance that is alive. So it is protoplasm that makes up the body of this interesting animal.

193. Let us find an amœba in a drop of stagnant water and watch it. It is not brown-colored like most of the mass on our

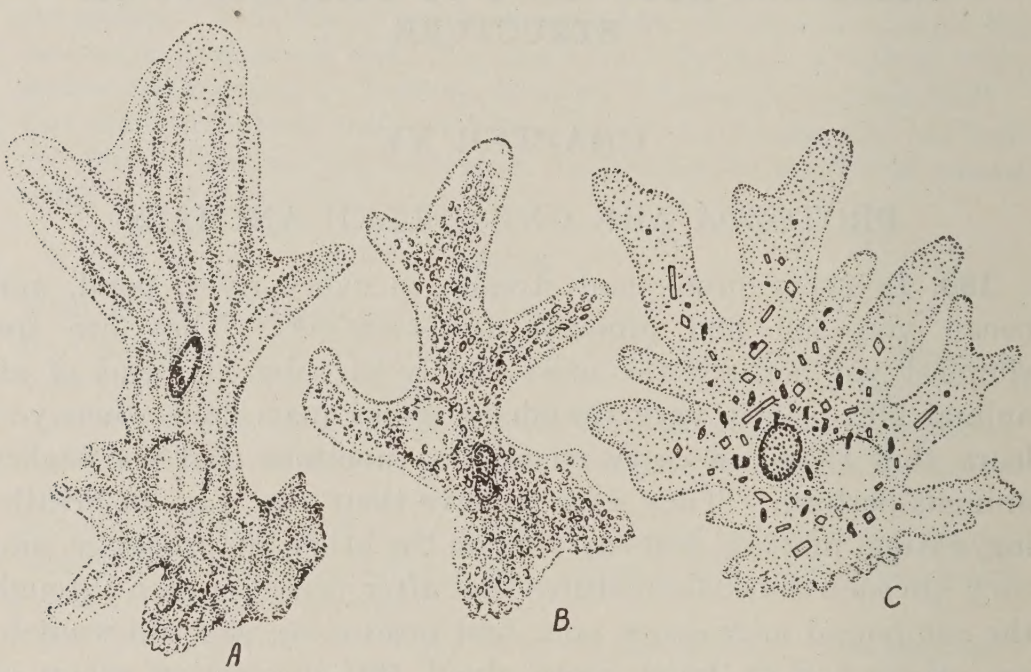


FIG. 99.—Different species of amœbae. (*Lane. From drawings by Professor A. A. Schaeffer.*)

microscopic slide, but is grayish white. It often appears to have a "salt-and-pepper" color and is made up of tiny granules, this structure being characteristic of protoplasm. In shape it is nearly round, thicker and denser in the center, and quite thin around the outside edges. Presently its shape changes as it sends out a roundish mass of thin protoplasm, called a **pseudopodium** (*sū do po'de um*), which means "false foot," for it is by these pseudopodia that the animal crawls about. More protoplasm flows along, reminding one of mucilage slowly flowing out of an overturned bottle. The pseudopodium becomes larger

and longer. Presently another pseudopodium begins to stream out, not far from the first one. The animal is moving forward. We wonder what is taking place. Now the hind part of the body is flowing over in a sort of slow, rolling motion, and we see that in this way the amœba crawls about and gets its food. Why does it do this? It is just protoplasm reacting to a stimulus. This time it is the stimulus of food, for we see these pseudopodia closing in around a small particle of plant matter. Over and beneath it as well as on each side the pseudopodia flow, until presently the food particle is entirely engulfed. Let's follow it for a moment. It is now entirely within the amœba's body, just a little ball surrounded by a watery fluid, by means of which the food is being digested. This tiny mass of food is known as a **food vacuole** (*vak'uōl*) and from such food vacuoles as this the protoplasm is nourished. Now we notice, over in another part of the cell, a small white circle acting queerly. It is getting larger, being filled with a watery mass which contains some solids. Now it is slowly moving over through the thin **ectoplasm** to the very edge of the amœba's body. And now it is bursting through to the outside, voiding its contents entirely out of the animal's body into the surrounding water, for this is the way that the **contractile vacuole** works. It is the amœba's one organ of excretion; for every living thing, no matter how small, has to have some way of getting rid of its wastes.

194. If we continue to watch this amœba long enough we may see it divide itself into two halves, for this is the way in which it reproduces. First the nucleus begins to elongate. Then the lengthening process continues as the nuclear material divides into two equal halves until it somewhat resembles a dumb-bell in shape. The two halves completely separate, and soon the rest of the animal's body likewise divides slowly into two parts, each half having one of the nuclei. Two amœbae now, instead of one! But which is the parent and which is the offspring? Both are just alike. The parent has now become two offsprings. But our amœbae are not doing anything now. Each one is just a roundish mass with very little motion. We have watched the

little creatures so intently this past hour, that we forgot to put a fresh drop of water under the cover glass and the slide has completely dried up. We shall not see anything more happen except the weakening and separating of the granules of protoplasm.

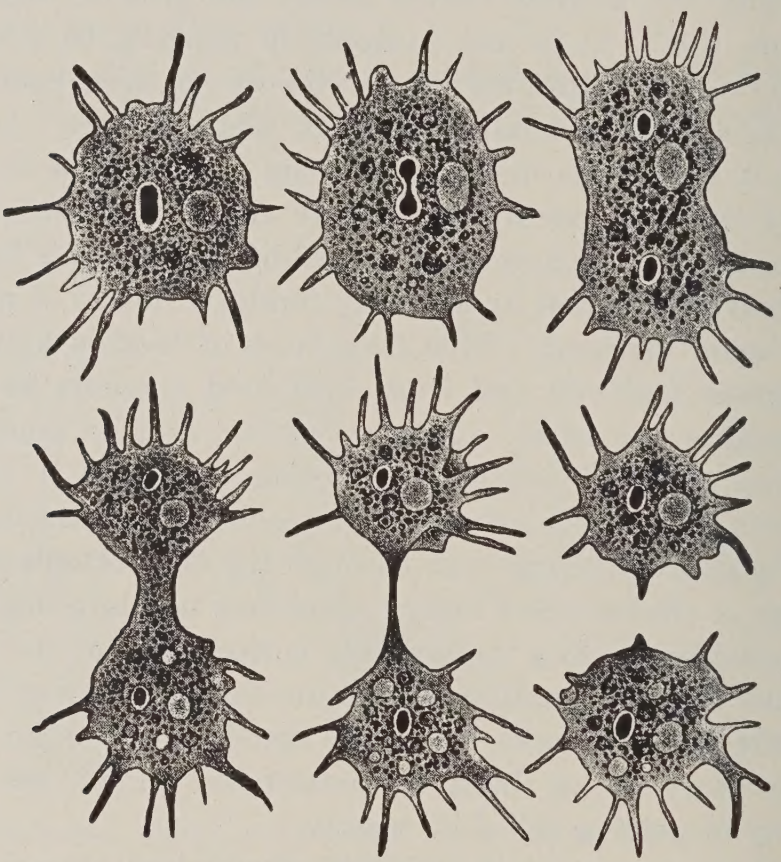


FIG. 100.—The amœba reproduces only by fission. Notice that the nucleus separates first. (*Atwood.*)

195. Paramecium.—Probably the commonest protozoan studied in school is paramecium (*par-am-e'she-um*), "the slipper animalcule." Paramecia, which are fairly common in stagnant water, may be found in scrapings from the sides of an aquarium, and in nearly any place where water has been standing long enough to allow the plant matter to break down and form food for these animals.

196. Making a Hay Infusion.—Any pupil can raise enough protozoa for his own study and amusement by making a hay

infusion. All one has to do is to go out into any field or vacant lot and collect a handful of dead grass. Put this into a jar of cold water and set it away in any warm place. Leave it for a week or two. Then take a tiny drop of the water that contains a bit of the broken-down plant matter and examine it on a slide under the compound microscope. Most of the tiny, grayish-white animals swimming around in the infusion will be protozoa.

197. Why Certain Species of Protozoa Encyst (*en-sist'*).—Where did the protozoa in our hay infusion come from? How did they get onto the hay? Since all protozoa are water animals, they must have come from some near-by body of water. But are aquatic animals like these found on the dead grass of nearly every field? The answer is "Yes, if there are any swamps, pools, or bodies of water not far distant." The reason is simple. Whenever the water in which these encysting forms live, begins to dry up, their lives are threatened, because they are aquatic. Nature has provided them with a means of escape. They form a thin but firm membrane around themselves and remain quiet. This membrane or capsule, being water-tight, keeps them from drying up. In this condition they are readily blown about by the wind and alight in all sorts of places, as does everything blown about in this way. Hordes of them perish, but many do alight in bodies of water, or even in low land, so that after the next rain their cyst is dissolved and they continue life as before. If you do not understand how they can apparently come to life again, just allow your hay infusion containing live protozoa to dry up and remain perfectly dry for a few days. Then add water, and after a week or two your animals will be as active as ever.

198. External Structure of Paramecium.—Paramecium is somewhat slipper-shaped. It is easily recognized by its form. The entire body is covered with minute (*mi nūte'*) hairlike projections called **cilia** (*sil'-e-ah*). Only under high-power magnification can you see these cilia, although you will frequently see disturbances in the water surrounding a paramecium while it is under low-power magnification. These are water currents set up by the rapid vibrations of the cilia. Many diagrams of

paramecium indicate that these cilia are only around the outer edge of the animal. On the contrary they are all over its body. By moving these cilia in a backward, sweeping motion paramecia

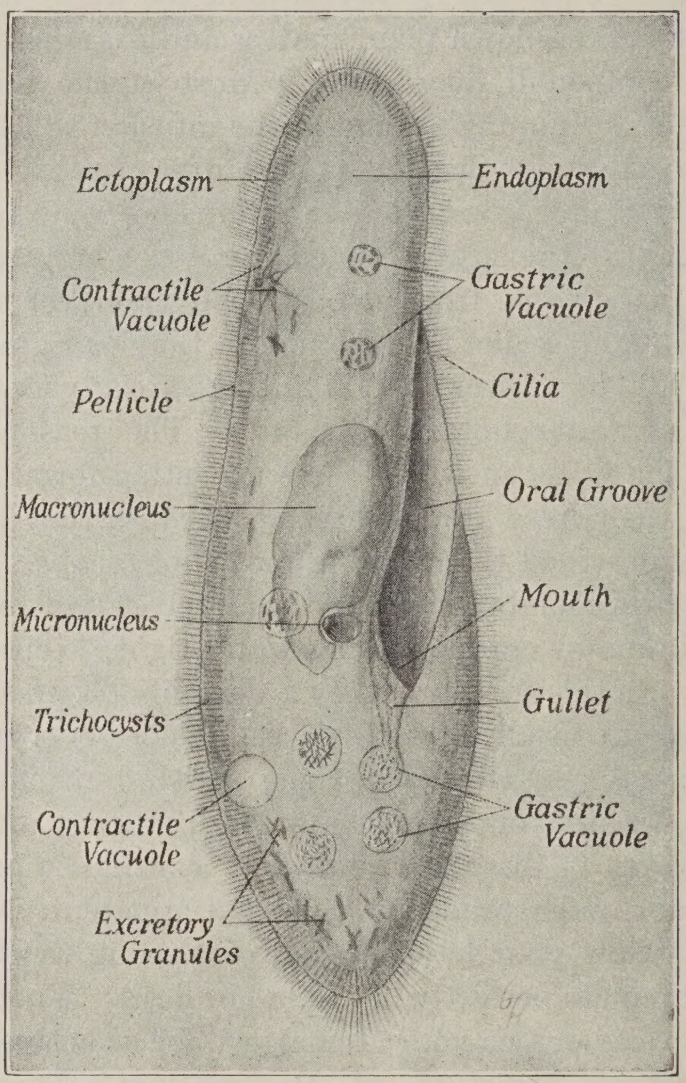


FIG. 101.—Paramecium. (*From Smallwood's Biology. Published by Lea & Febiger.*)

propel themselves rapidly ahead. One end of the animal is rather blunt, the other end being somewhat pointed. Which is the anterior (front) end—the end that moves ahead most of the time? Only by watching the animals can you answer this question. About two-thirds of the way back from the anterior

end is a fairly large **oral groove.** In this groove they scoop up their food as they swim along. Have you watched a paramecium swim along in its twisting, spiral course? Can you tell how it is done? Does the fact that one end of the body is somewhat flattened, help to explain this motion?

199. Internal Structure of Paramecium.—From the oral groove the food particles pass backward through the funnel-shaped **gullet** which empties right into the mass of protoplasm. By the slow movement of this protoplasm the remainder of the more or less solid food taken in by the paramecium passes in a nearly complete circle around the body and is discharged at a definite point posterior to the mouth. This process has nothing to do with the contractile vacuoles. The other wastes are excreted by means of the two **contractile vacuoles,** one at each end of the animal. Sometimes these appear as round white circles and when they are "working" they often are star-shaped, the points lengthening and shortening in a very peculiar fashion. Two **nuclei** are also present, usually not far from the center of the body. They are close together, one being large and the other very small.

200. Aside from fission, paramecium has a supplementary process closely related to it, called **conjugation.** Under certain conditions, none too well understood at present, these animals seem to feel the need of gaining vitality. All paramecia are structurally alike, for there is no such thing as sex among these one-celled animals; and when two of them conjugate, the intervening cell wall ruptures and the micro-nucleus which is the smaller of the two nuclei, crosses over from one animal into the cytoplasm of the other animal. Thus each of them receives the micro-nucleus which formerly belonged to the other paramecium. Here we have an **exchange** of nuclear material. Apparently there is a considerable degree of irregularity as to when and how often conjugation occurs. Formerly it was thought that only a limited number of divisions by fission were possible before conjugation had to take place in order to sustain vitality, but recent observations seem to disprove this.

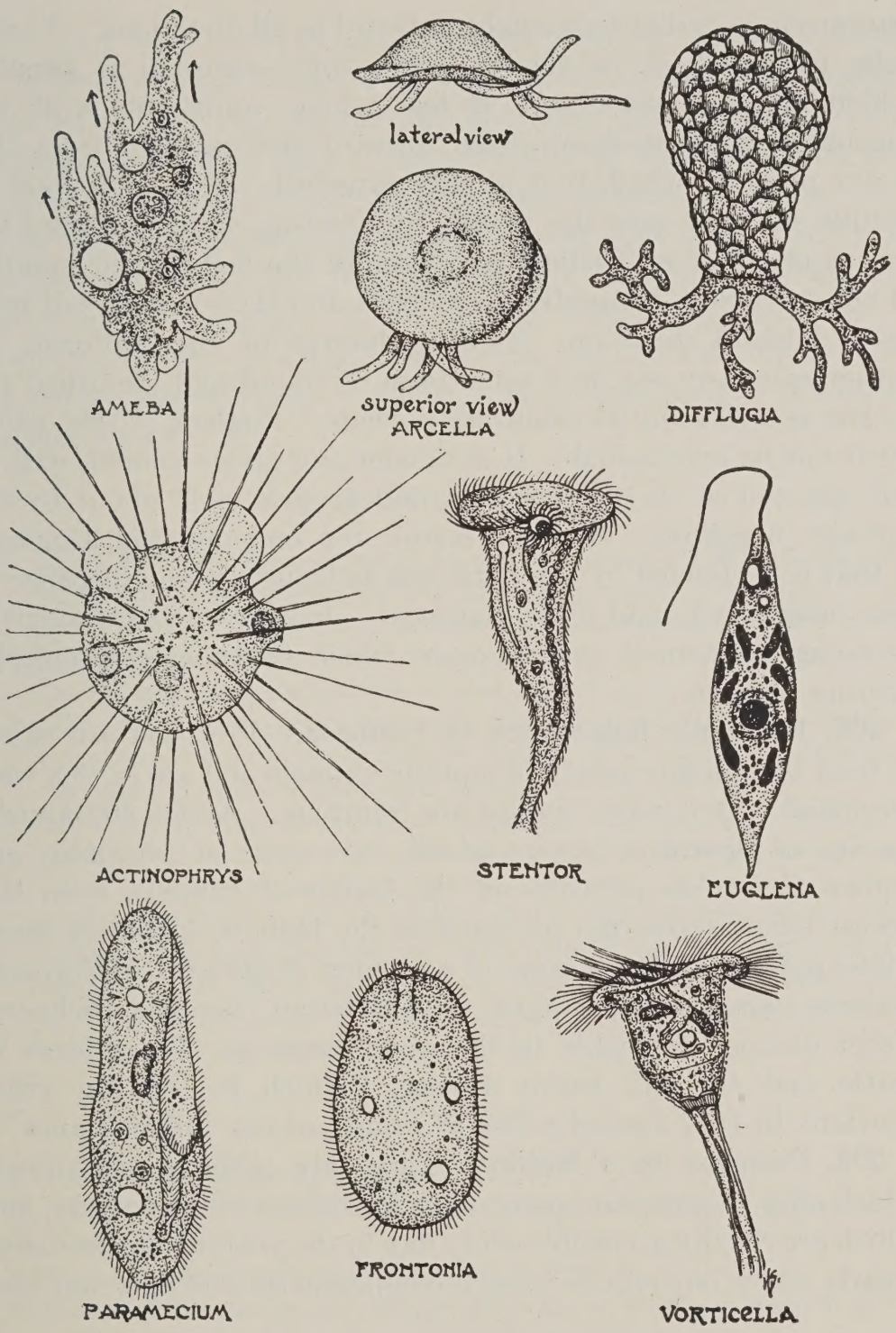
201. The significance of conjugation is not entirely clear. Some students contend that its importance to paramecia is uncertain, while others see the process of conjugation as a possible beginning of what we know as sex in the higher organisms.

202. How Paramecium Defends Itself.—One would hardly expect so small a creature as paramecium to fight. When it merely bumps into something, it just backs away or moves around the obstacle, but if persistently annoyed by an enemy it shoots out dozens of tiny darts called **trichocysts** (*trik'o sists*) which are usually effective in driving the enemy away.

203. Amœba and Paramecium Compared.

	Amœba	Paramecium
Habitat	Near food at bottom of water	Anywhere in the water
Food	Microscopic plant and animal matter	The same
Locomotion	Pseudopodia	Cilia
Excretion	One contractile vacuole	Two contractile vacuoles
Defense	None	Trichocysts
Reproduction	Fission	Fission and conjugation
Food-getting	Engulfing	Scooping it up in its oral groove
Shape	Never twice alike	Fixed, slipper-shape
Cell membrane	None	Always present
Irritability	Reacts to all stimuli such as light, heat, etc.	The same

204. Other Protozoa.—While looking for amœba and paramecium, one frequently finds other forms of protozoa. One of the commonest is Stylonychia (*sti lo ni'ke-ah*). Smaller than paramecium, it is similar in shape although not so long. It is readily identified by the three or four stiff bristle-like structures protruding from either end. Bodo (*Bo'do*) and Chilomonas (*Ki lo mo'nas*) are other fairly common forms, both much smaller and more nearly round. One beautiful form is Actinophrys (*ak-tin-of'-ris*) sol. Named from the sun, it does bear a resemblance in shape and it has dozens of tiny cilia, larger and longer than those of



COMMON PROTOZOA

FIG. 102.—Several common species of protozoans usually found in hay infusions such as any high school boy or girl can make. *(Copyright by General Biological Supply House, Chicago.)*

paramecium, radiating straight outward in all directions. Vorticella (*vor-te-sel'-ah*) is always interesting because it is **sessile,** which means "attached." It has a long, contractile stalk by means of which it shoots itself forward and outward from the water plant to which it is usually attached. If it finds food it readily sucks it into the mouth by creating water currents by means of the row of cilia that surround the bell-shaped mouth. If not successful, it rapidly draws back and thrusts itself out in a more hopeful direction. Stentor, largest of the protozoa, is rather rare, but one may sometimes be found and identified by its size as well as by its chain-like nucleus. Euglena (*U-gle'-nah*), must not be overlooked. It is slender and green colored, with a red eye-spot at its anterior end, and propels itself about by its tail-like flagellum. Another reason for remembering Euglena is that it is claimed by the botanists as being a plant (because it has chlorophyll) and is as vigorously claimed by the zoölogists as being an animal (a protozoan which feeds on chlorophyll-bearing plants).

205. Economic Importance of Protozoa.—Protozoa are eaten as food by a great variety of aquatic animals and are in this way beneficial. But many species are injurious. About 400 known species of Sporozoa (*spo-ro-zo'-ah*), one class of protozoa, are known to live as parasites in the bodies of animals, from the lowest forms above the protozoa to the highest, including man. These parasites are the cause of a number of diseases: all forms of malaria, amœbic dysentery, and African sleeping sickness. Other diseases traceable to the same cause are Texas fever in cattle and the silk worm disease, "which in thirteen years previous to 1867 caused a loss in France of one billion francs".[1]

206. Protozoa as a Hobby.—There are perhaps no animals which offer so great an opportunity for recreation and study, and which are readily accessible every day in the year, as the protozoa. Nearly every boy enjoys using a compound microscope, and here

[1] *Manual of the Common Invertebrate Animals*, by Henry S. Pratt, page 48. P. Blakiston's Son & Co., Inc.

are more than seven thousand species of living animals that offer "good hunting in a drop of water." Recently, small microscopes have been put on the market which sell for less than twenty dollars and which give a magnification of 300 diameters, large enough to study several dozen species of protozoa. The book, **Life of Louis Pasteur,** gives one a good idea of the thrills and enjoyment that this famous scientist got in studying these microscopic animals. After having learned to recognize the common forms, one may always find hundreds of others whose ways are still different. Again, it is always possible to discover a new species.

Interesting Projects

1. Examine under the compound microscope, slides made from water collected from (*a*) a spring, (*b*) the city water supply, (*c*) a pond or lake, and (*d*) a stagnant pool or any water that has been standing for some time in any wooden dish or container out of doors. Determine which source has the greatest number of one-celled animals in it.
2. Make several hay infusions by allowing a handful of hay or dead grass to remain in a jar of water for two weeks. Study and make drawings of the different kinds of protozoans which you will find there.
3. Take two or three glass jars to the edge of some pond or swamp. Fill the jars half full of the water and add a few of the decaying leaves usually found beneath the surface of the shallow water. After taking the jars home allow them to remain undisturbed for two or three weeks. Then, using a clean medicine dropper, collect several drops of water from the surfaces of the leaves, and make up slides. If you find amœbae, study their habits, especially the rolling movement of the protoplasm when the animals move about.

Review

1. Are protozoa plants or animals?
2. Name three or four widely different places in which protozoans are commonly found.
3. How may these organisms affect human life?
4. Compare the amœba and the paramecium as to shape, method of locomotion, reproduction, and method of food taking.
5. Name one animal which is also claimed by the botanists as being a plant.
6. Tell two ways in which protozoa are economically important.

Define

amœba
cilia
conjugation
contractile vacuole
ectoplasm
encystment
engulf
fission
food vacuole
hay infusion
paramecium
protozoa
pseudopodium
sessile
trichocysts
zoölogist

CHAPTER XVI

SOME OF THE MANY-CELLED INVERTEBRATES ARE WELL KNOWN

207. The invertebrates include more than a half million different species of animals, none of which possess a backbone or spinal column. This half (it is really more than half) of the whole animal kingdom is so numerous, so varied, and in many ways so unique in the myriad of forms which they possess, that to many persons the invertebrates are even more fascinating than are the vertebrates.

You have always known certain invertebrates, such as earthworms, butterflies and many other insects, starfishes, snails, clams, and oysters. You have used sponges, and when you were very young you probably played with sea shells (mollusks). You have read about jellyfishes, devil-fishes (the octopus), sand dollars, hook worms, and many other invertebrates. Now for a speaking acquaintance with a few of these interesting forms.

208. Sponges.—We seldom think that the common bath sponge is an animal, since it has no eyes, feet, and other organs which we naturally think of as belonging to an animal. What we have been calling a sponge is really only the tough skeleton of the animal. The softer parts have been taken away. Sponges are all aquatic. Most of them live in the ocean, attached to rocks, shells, and other objects at the bottom of the water. One form, **spongilla** (*spun-jil'-ah*) is a fairly common fresh-water sponge. Sponges are classified into three groups; horny, limy, and glassy, according to the material of which their skeletons are composed. Some of them are beautiful, such as the Venus' flower basket. The sheep's wool sponge is the most important sponge commercially. Thousands of these animals are collected

every year and the yield amounts to approximately $250,000 annually. Other forms which should be mentioned here are the boring sponge, the red sponge and the urn sponge. The skeleton of a sponge is usually made up of many tiny **spicules** (*spik'ūlz*) some of which resemble toothpicks. Others are seen to be three-pointed, slender, delicate things if you look at them under the microscope. In every living sponge, water is drawn in through many small openings, and thus the sponge gets whatever food may be in the water, which is later forced out through one or more large openings. Sponges reproduce in three ways; by budding, by forming gemmules, and by sperms and eggs. Budding consists in the formation of a tiny growth somewhat resembling a roundish bud on one side of the body. This bud grows and in time becomes like the parent. Then it breaks away and forms a new organism. Under certain unfavorable conditions the essential parts of the sponge migrate to the center of the sponge body and secrete a protecting capsule around them. This structure is known as a gemmule. Later it falls to the bottom, attaches itself to rocks or other solid objects, and grows into a new sponge. When the sponge reproduces by fertilized eggs, they hatch within the sponge itself and are thrown out as tiny larvae. After a short time they attach themselves to some solid object on the bottom and develop into sponges (See Fig. 223).

209. Perhaps at the seashore you have wandered up and down the riffraff line which consists of seaweeds and a hundred different things that have been thrown up on the shore by the waves. Very likely you have seen something there that looked more like a sponge than anything else, yet didn't have the right shape, as it had many branches. This probably was Chalina (*kal-i'-nah*), a true sponge which the fishermen call "dead men's fingers." They are curious forms, and are well worth looking for, as they are quite abundant and will repay one well for the short time that it usually takes to find them.

210. The sponges that are sold in the drug stores live only at the bottom of the warmer seas. Many are found near the West Indies, off the Florida coast, and in the Mediterranean

sea. Divers locate them by looking down into the clear waters through glass-bottomed buckets, and then merely pull them off the rocks, shells, and other hard substances on the ocean floor. After being collected, they are either buried in the sand or put on drying racks where the soft bodies decay; and after the skeletons are cleaned, bleached, and trimmed, they are ready for the market. Only those sponges that have the softer horny skeletons are of value commercially.

211. Coelenterates.—This word **coelenterate** (*se len'ter āt*) means **a hollow digestive cavity** and it well describes this unusual

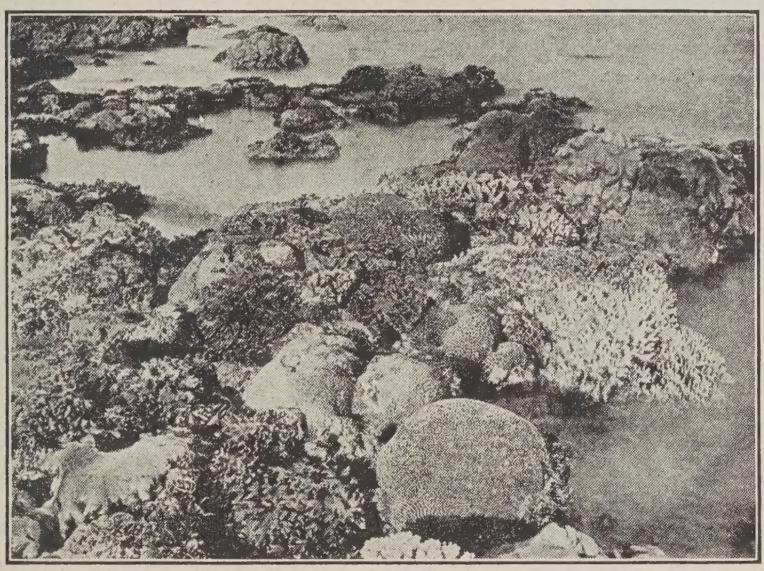


FIG. 103.—A reef containing many varieties of corals. (*Holmes.*)

group of animals. Theirs *is* a hollow digestive cavity in a more or less cylindrical body, which is composed of three layers: the outer **ectoderm;** and inner layer, the **endoderm,** and a middle layer, the **mesogloea,** (*mes-o-gle'-ah*) which is really the skeleton or supporting layer.

Who has never heard about the coral reefs, or seen a jellyfish? For jellyfishes were known long before 1744 when Trembley compared a hydra to the octopus. These animals too, are all aquatic. Probably the jellyfishes you have found at the sea shore were umbrella-shaped creatures with arm-like tentacles (*ten'-tak-elz*) hanging down underneath. They are carnivorous

(*kar-niv'-orus*) creatures, which feed upon small fishes, crustaceans, and even upon one another. They move about by opening and closing their "umbrella". They catch their food by grasping it in their tentacles, armed with hundreds of tiny darts which penetrate their victim and paralyze it so that it cannot move.

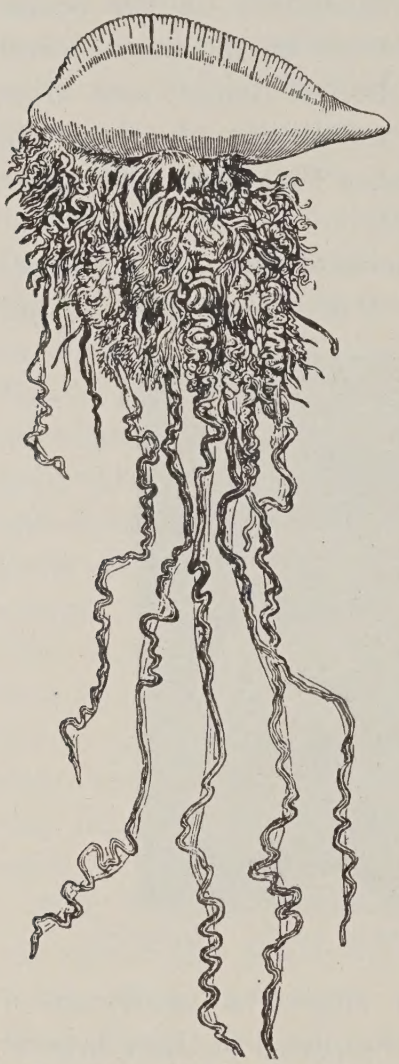


FIG. 104.—Portuguese Man-of-War, *Physalia*. The various members of the colony are adapted for different functions, showing a division of labor. It is a curious fact that only male Portuguese Men-of-War are known. The females have not yet been observed. (*Holmes.*)

212. You are fortunate if you have ever seen the Portuguese Man-of-War (Physalia [*fi-sā'-le-ah*]). Its large pear-shaped float is five or six inches across and is filled with air which buoys up the colony, for it *is* a colony. Although it appears to be one animal, it actually consists of several different kinds of individuals. These function differently. Some of them are reproductive, others secure the food, while still others protect the colony by their stinging cells. Its home is in the Atlantic, especially in the Gulf Stream, where its beautiful shades of iridescent (*ir-id-es'-ent*) blues and pinks gleam on the water surface like dancing prisms. And hanging down from the float is a cluster of tangled parts, the feeding and reproductive individuals. Mayer[1] says of them: "When the wind blows, the long tentacles stretch out fully fifty feet, thus forming a drag to prevent a too rapid drifting of the colony."

213. Hydra is also a related species. It lives in fresh water and may fre-

[1] *Seashore Life* by Alfred G. Mayer. Published by the New York Zoölogical Society.

quently be seen clinging to the sides of aquaria or hanging, head downward, from the surface of the water. Hydra is small, being only ⅛ to ½ of an inch long. Its somewhat slender body has a row of elongated, hollow tentacles around the mouth which are ever ready to grasp any small crustaceans (*krus-tā'-she-ans*) (Sec. 237) or other minute animals that have

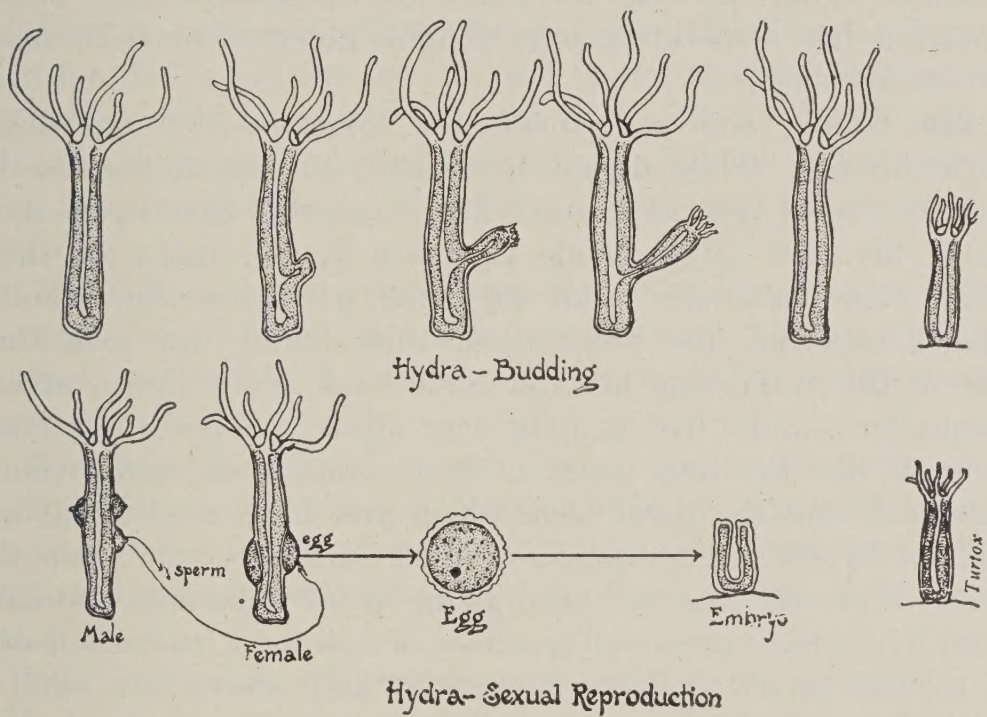


FIG. 105.—Hydra with tentacles extended. (*Copyright by General Biological Supply House, Chicago.*)

wandered too near it. Hydra's color is greenish white and so it is not easily seen, but if you have an aquarium or even a jar of stagnant water which has been an aquarium, it may pay you to look carefully for hydra. If the vessel isn't jarred when you look, you will probably see it if present. If you can put some daphnia or other very small crustaceans into the water, you will be interested in watching it catch them.[1]

[1] A few minutes of time can be used very profitably on some field trip by collecting a supply of the tiny crustaceans, which are so abundant in many fresh water pools, especially where the water is stagnant.

214. Some people call the Ctenophores (*ten'-o-fōrz*) "sea walnuts" which, if we may judge by their shape, is a good name. They drift about over the ocean surface, often in enormous schools, for they are sometimes very common. Many of them give off a pale, phosphorescent light in the evening. I remember one evening at Woods Hole, Massachusetts, just outside the harbor, when the water thrown up behind the motor boat was just a sparkling mass of lights given off by these small surface-dwellers.

215. Corals and sea anemones, (*an-em'-o-nēz*) are other coelenterates. These do not drift about, but remain fixed to the rocks or coral reefs and other firm supports—that is, in their adult life. Of course while they are young, many of them "sow their wild oats" and as young jellyfishes they wander about, exploring the waters near their home; but soon they tire of this wandering life and come back, settle down, attach themselves, and "live happily ever after." When these coral animals die, the limy parts of their minute skeletons remain attached, and the coral reefs which you have read about are formed by the accumulation of their skeletons, one upon the other, a process that has been going on for centuries. Perhaps your school has a preserved specimen of Astrangia (*as-tran'-je-ah*). If so, you should examine it carefully as it shows how coral is formed.

216. Worms.—At first thought, worms may seem repulsive, but when we learn about their structure and habits, and how some of them cause diseases in man, we recognize them as an important group, about which we should know more. Worms are of three kinds: **round, flat,** and **segmented.** The roundworms and flatworms are much simpler than the segmented or annelid (*an'-e-lid*) worms. The first two groups are usually of small size, and generally without paired appendages. For the most part, they are very slow of movement and many of them are parasites.

217. A good example of a *roundworm* is the hookworm (Necator, *ne-kā'-tor*), which is from ¼ to ½ inch long. The

hookworm is very common in the southern states especially among the poorer classes of people and those who do not live under sanitary conditions. The worms gain access to the body by boring through the skin of the feet or hands. From here they move about, entering the blood stream, the muscles, and the small intestine. The eggs pass out with the wastes and hatch into young worms which live in the moist earth. The hookworm disease does not occur in the northern states, the climate being too cold for the young worms. Persons suffering from this disease soon lose their initiative and ambition. Whole families often suffer in this way, becoming listless, and indolent. The preventive measures are the use of sanitary toilets and the wearing of shoes.

218. You may have seen the tiny, hair-like worms called "vinegar eels," which are sometimes found in vinegar, and feed on the "mother" in the vinegar. They rarely live in the human body.

The little "horsehair" worms often found in stagnant water and in shallow brooks used to be thought by some persons to have originated from hairs which had fallen into the water from some passing horse and had sprung into life there. This, of course, is not true.

219. Tapeworms, discussed more fully in the chapters on "Health," are examples of *flatworms*. Liver flukes are still others. The latter live a parasitic life in the liver of sheep and a few other animals. Only in China and Japan have they been found in man. The planarian (*plan a're an*) worms (very small flatworms, usually living in fresh water) show a remarkable ability at growing parts of the body which have been destroyed. This ability, known as **regeneration of lost parts,** has been demonstrated many times in the laboratory by cutting these worms in halves. Each of the two halves usually grows the missing part and the worms live, apparently as well as ever.

220. The *segmented* or annelid worms are more highly developed than the flatworms and roundworms. They have long, segmented bodies with a definite head. They possess some-

what elementary digestive, excretory, and nervous systems, and in other ways show that they are fairly complex. Some are hermaphroditic[1] (*her maf ro dit'ik*) while others are either male or female.

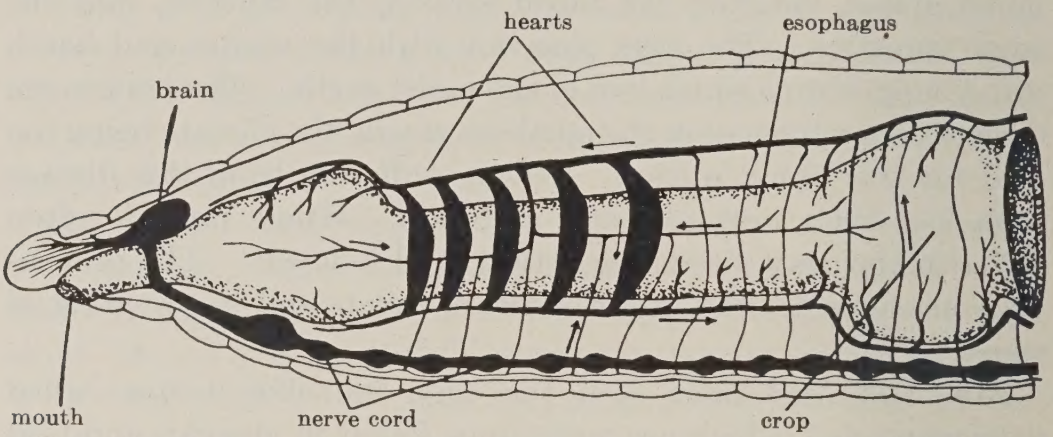


FIG. 106.—Diagram of the earthworm showing the digestive, the nervous, and the circulatory systems in their relations to each other. Only the anterior end of the worm is shown here. There are five pairs of hearts which pump the blood forward dorsally and backward ventrally as shown by the arrows. This flow may easily be observed in any live earthworm. (*Atwood.*)

221. The familiar earthworm is a good example of an annelid, as is also Nereis (*ne'-re-is*), the greenish-gray sandworm so often seen in the sand at the seashore. The tufted worm is one of the most beautiful of all the worms. In the muddy beaches near the low-tide mark you will find them, burrowing in the mud. Around the head are three pairs of bright red gills besides a number of straw colored tentacles with which they grasp their food. When these worms are dug up out of the sand they are really beautiful, because of the bright color of the fringing gills.

222. Echinoderms.—These, as their name implies, are the spiny-skinned animals, for **echinos** (*e-ki'-nōs*) means **hedgehog,** and **derma** means **skin.** They are the denizens of the deep, and yet you have seen some of them many times. The five classes include the familiar starfishes, sea urchins, sea cucumbers, brittle

[1] Certain lower forms of animals possess two sets of glands which produce both sperm and egg cells in the same individual. Such animals are said to be *hermaphroditic.*

stars, and sea lillies. These animals are radially symmetrical; that is, the body possesses a symmetry of parts which most persons wonder at when they first notice it.

223. As to habitat, they are all marine. Some of them, such as starfishes, live near the shore while others live farther out, even in the greatest depths. They crawl about over the sandy or muddy bottoms, feeding on small animals and plants as well as on organic matter found in the sand, mud, and water. A few species can swim, but this ability is not general. One of the interesting things about these spiny-skinned animals is the way they walk or crawl about by means of water. The mechanism for locomotion is called a **water vascular system.** Let us take the starfish as an example. Every starfish has five arms—for all the echinoderms (*e-ki'-no-derms*) except a few, such as Solaster, are made up symmetrically of five (or multiples of five) parts, all of which are alike. On the lower surface of each arm are dozens of tiny, fleshy projections, the feet. These are hollow and generally have sucking disks at the ends. They are filled with water and are then pushed outward. When they come in contact with any solid object, the sucking disks are attached to the object. Then, by simply contracting the muscles, the starfish pulls itself along. These ambulacral (*am-bu-lā'kral*) (walking) feet are a very ingenious means of not only clinging to almost any surface, but of allowing the animal to go about wherever it pleases. Perhaps you have seen live starfishes in a salt water aquarium and wondered how they ever could crawl up the sides of the smooth glass. It was possible only by means of the ambulacral feet.

224. These feet can also cling to many objects very firmly, as you know if you have ever seen a starfish opening a clam or an oyster—a delicacy to every starfish. And this fondness for oysters brings us to another interesting point.

225. The men who raise oysters know about this fondness of starfishes for oysters, but for years they used to destroy the starfishes by cutting them in two and throwing them back into the water, killing them as they supposed. But they did not then

know about the wonderful ability which all of this group possess in growing, or, as it is usually called, "regenerating" lost parts. If a starfish loses an arm or even several of them by the attack of some enemy, it simply grows new ones to replace the ones thus lost. I have seen this demonstrated by firmly seizing a starfish by an arm, much as a lobster might do, and holding on firmly. The starfish waited a reasonable length of time to see if I merely wanted to hold hands. Then, deciding that I was no friend of his, he just seemed to let go and dropped back into the water and to safety, leaving me with his arm. After the starfish had remained in a sea-water inclosure for several days, the wound healed and straightway another arm began to grow. The only excuse a starfish can offer for possessing only four complete arms and a stub of the fifth one is that it has not yet had time to complete the growth of the fifth arm. Today the oystermen keep the starfishes out of the water until they are very sure that they are dead before throwing them overboard. The sea cucumbers, another order of echinoderms, can do even better than this; they can regenerate a new digestive system.

226. Among most of the echinoderms the sexes are separate. They reproduce by sperm and egg cells. These curious "spiny skinned" animals live in all parts of the world, there being nearly four thousand species of them.

227. Mollusks.—What child does not possess among his treasures one or two sea shells? What does any small child do at the seashore, after playing in the sand awhile, but to go around hunting for mollusks? He doesn't call them that. He doesn't know all about their mantle, their gills, and just why they have to carry their houses around on their backs; he just appreciates what he does know about them—their varied shapes and the iridescence of the mother-of-pearl lining when the sunlight shines upon it.

Yes, mollusks form the sea shells. You probably know that there are many illustrated books in the library which tell much about this group of animals. But find the mollusks yourself and then you will know whether the books are true; and you

may discover many of the interesting things which they leave untold.

228. The 60,000 or more species are divided into the three large orders in addition to another smaller one whose members are either worm-like or covered with rows of plates. The three orders referred to are Gastropods (*gas'tro pods*), which include the snails and one-piece shells; Pelecypods (*pe les'e pods*)—oysters, clams, and mussels; and the Cephalopods (*sef'al o pods*)—the nautilus, the octopus, the cuttlefish, and the squid.

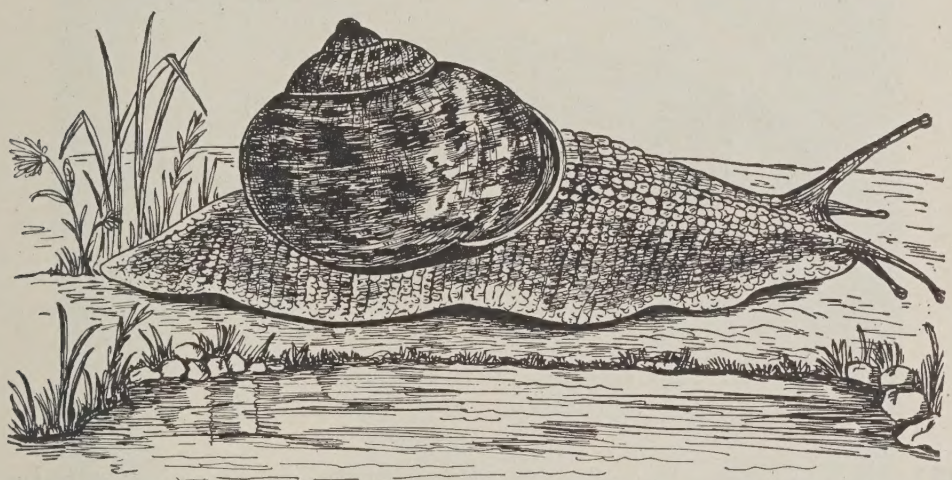


FIG. 107.—The common snail is a mollusk. (*Corwin and Corwin.*)

229. Have you ever thought why these mollusks need so good a protection?—why they need to carry their houses around on their backs? The reason is that most of the mollusks are soft-bodied forms, a great many of which live in the ocean. In the ocean also live thousands of animal forms roving about ever on the watch for food, and these slow-moving, soft-bodied mollusks would indeed be an easy prey were it not for their shells. Perhaps you know such forms of mollusks as (1) the squid, which darts rapidly backward at the approach of its enemy and conceals itself by shooting out a black "ink" screen; or (2) the octopus, (devilfish) which has two large eyes and eight or ten long, muscular arms with suckers. These do not need shell protection. But the slow-moving and, therefore, helpless forms

must be protected in the struggle for existence or their race will perish from the earth; hence the shell.

230. Inside of the shell is the real body which is made up of four parts: the head, in front; the viscera (internal body parts); the mantle (a veil of flexible skin which encloses the viscera); and the foot (a tough, fleshy organ by which the animal creeps along). No doubt you have seen, out in the garden, a snail or a garden slug crawl along on a rock or some old board. These land forms breathe by a lung instead of by gills.

FIG. 108.—Edible salt water mussel, *Mytilus edulis*. (*Reese.*)

231. In the two-shelled or bivalve mollusks there is a tube or siphon which has two canals running lengthwise through it, and which opens to the outside. When the clam or other member of this group[1] allows its shell to open, this siphon (often called the neck) is stuck out and sea water containing microscopic food is drawn in through the **incurrent opening.** After the food is extracted, the water is expelled through the other or **excurrent opening.** Such forms as clams, mussels, scallops, and oysters are well protected against most enemies because of their ability to close their shells so tightly. The starfish, however, has a way to get around this difficulty. It doubles itself over the victim and exerts a slow but strong and steady pull outward on both valves or shells at the same time. After a while the adductor muscles of the mollusk reach the point of exhaustion, so that

[1] Tagelus and some other forms possess two entirely separate tubes.

from sheer fatigue it has to yield and allow its two valves to be pulled apart. Then the starfish consumes the contents.

232. Mollusks do not shed their shells; on the contrary, the shell is continually added to and thus increased in size as the animal grows. No doubt you have noticed on some snail or nautilus the rings or whorls of the shell which grew to accommodate the body of the growing mollusk within. Oliver Wendell

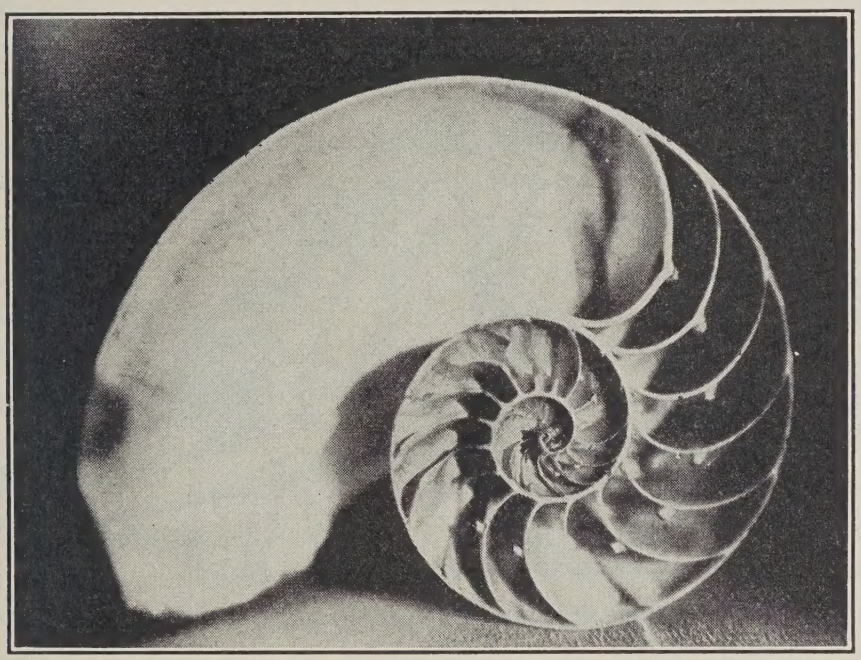


FIG. 109.—When young, the nautilus has a shell containing only one space or "chamber," but as it grows and needs more room, other "chambers" are added. It is in the latest one of these that the nautilus lives.

Holmes has beautifully pictured this accommodation in his poem "The Chambered Nautilus."

> "Year after year behold the silent toil
> That spread his lustrous coil;
> Still as the spiral grew,
> He left the past year's dwelling for the new.
> Stole with soft step its shining archway through;
> Built up its idle door,
> Stretched in its last-found home, and knew the old no more."

233. Arthropods.—Arthros is the old Greek word for **jointed,** and **poda** means **feet** or **legs;** so these animals are well named, for

they all have jointed legs. Someone has referred to them as "the future rulers of the earth." Surely this group which includes, among others, the insects, and comprises more than 600,000 species, are man's rivals for supremacy. But that is another story which we shall come to presently.

234. The arthropods (*ar'-thro-pods*) are not only a fairly well-known and very important group, but the largest phylum of the whole animal kingdom. They are, besides, the most specialized

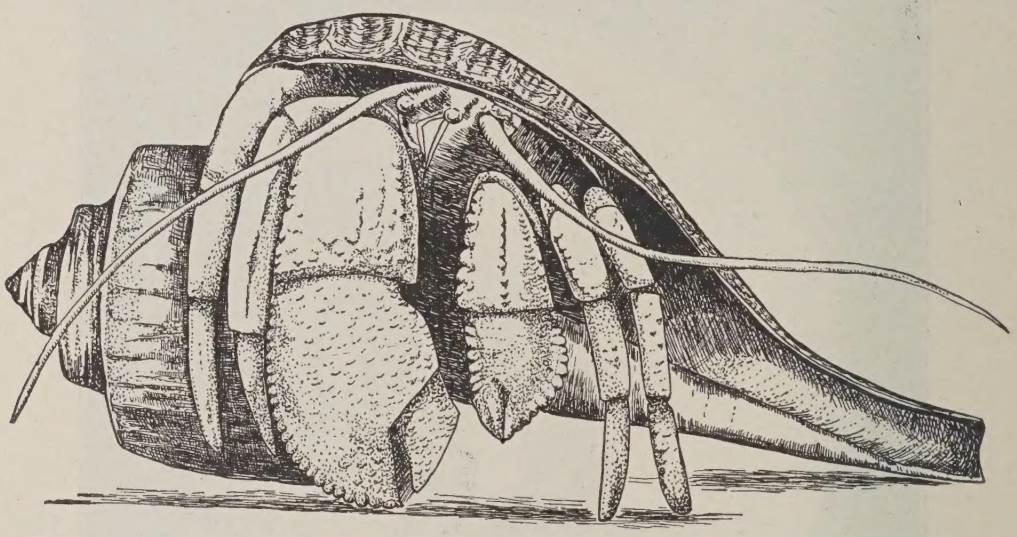


FIG. 110.—The hermit crab in a borrowed home. (*Corwin and Corwin.*)

and highly developed group among the invertebrates. You need no introduction to the butterflies and moths, the grasshoppers, lobsters, and spiders, for you have always known them. Probably you saw them before you even knew their names.

These arthropods are of four kinds: myriapods (*mir'-e-o-pods*), insects, crustaceans, and arachnids (*ar-ak'-nids*). They will be easily remembered by the first letters which spell the word **mica.**

235. The appendages, which are varied, serve different purposes among these arthropods. They function as sense organs and organs of locomotion as well. The anterior pair, when present, form the antennae or feelers. With most species one or more pairs form the jaws. Those on the thorax serve for locomotion and, in the strictly aquatic forms, aid in respiration, since

the gills are commonly attached to the dorsal end and wave to and fro in the water as the animal moves about, thus taking in more oxygen. The abdominal appendages serve for locomotion, and for the protection and transportation of the eggs and young. Some appendages serve other purposes. The spinnerets which spiders use while making their webs, and the stings and egg-laying structures of the insects are examples.

Arthropods are often highly colored. Some of them compare favorably with the birds as being among the most beautiful of all living creatures.

236. Their internal structure is the most highly developed of all the invertebrates. Salivary glands are present in nearly all the land forms. Small glands serve as kidneys for the excretion of wastes. A circulatory system is present but is not well developed. All have blood, greenish yellow in color. Many of the crustaceans have no heart but the blood is pumped, or rather pushed around, by the contractions of the muscles as the animals move about. As a rule the primitive heart is dorsal. This location is just the opposite to what we shall find in the vertebrates. Respiration is carried on by gills in the aquatic forms and by tracheae (*trā'ke e*), usually through spiracles (*spir'-ak-lz*) in the land forms. The muscular system is well developed. The nervous system is made up of several pairs of ganglia connected by nerves. The anterior pair of ganglia serves as a brain, from which nerves run out to the various sense organs. For the most part the sexes are distinct.

237. Lobsters, crabs, and crayfishes are good representatives of the crustaceans. Their most noticeable characteristic is their exo-skeleton, a tough shell of lime and chitin, which covers the entire outside of the body, even the eyes, and which they molt or cast off several times during their period of growth. Each new exo-skeleton is, therefore, larger than the previous one.

238. Crustaceans are encased in an armor all their own. They rival King Arthur's knights in their protection. At first this armor seems very unwieldy and stiff, but just notice how the first joint bends one way and the next joint bends at right angles

to it. This arrangement allows them a freedom of motion that one would at first, hardly expect. Have you ever tried to pick up a live lobster or crab? Weren't you surprised how easily and quickly he reached out to grasp you, his enemy, with those

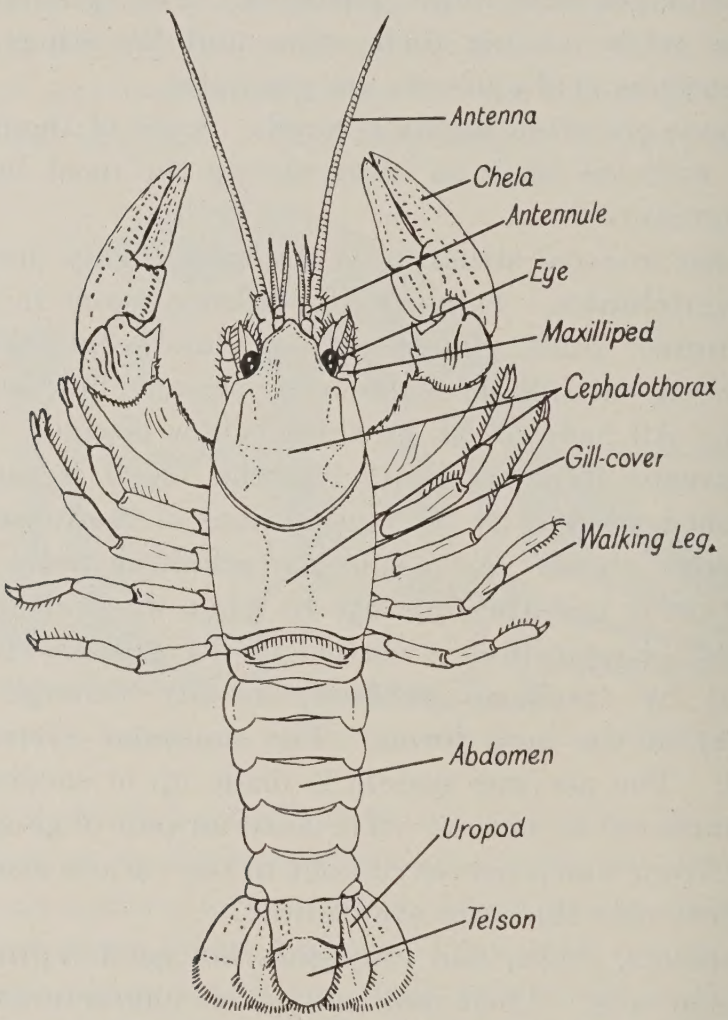


FIG. 111.—The common crayfish is a crustacean. (*Lane.*)

strong claws? Being thus encased, he cannot grow steadily as we do. When the armor gets too tight, it is shed and growth takes place rapidly until the next armor is formed. In this waiting period crustaceans remain in hiding from their enemies, for without any armor they seem to realize what easy victims they would be. Dr. Herbert E. Walter puts it very well: "They are

very, very modest when they have no clothes on". Of course it is purely a case of protection from their many enemies in the water, for nearly all crustaceans are aquatic.

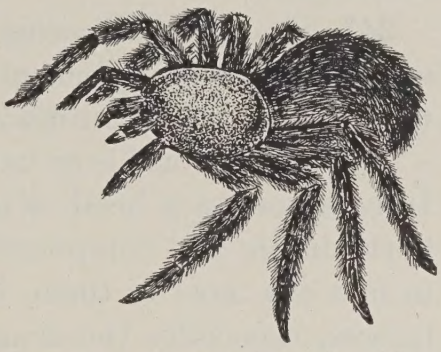


FIG. 112.—Tarantula spider. (*Corwin and Corwin.*)

239. The arachnids are a peculiar group and none too well known. The spiders and scorpions belong to it. The horseshoe crab is another form well known at the seashore. These animals never have antennae. The head and thorax are fused together into a cephalothorax (*sef-al o tho'rax*). Spiders have eight eyes and eight legs, "an eye for a leg." Probably the spiders are best known for their remarkable ability as web spinners—the first spinners in the world. This web may serve as their home, as a net for catching their food, or even as a mode of transportation, as in the case of the ballooning spiders.[1] Some webs are beautiful—really are works of art. Ordinarily, spiders kill their prey by biting or by stinging it. Scorpions are elongated arachnids with a long abdomen which is composed of six segments, with, usually, a poisonous sting at the posterior end. There are from three to six pairs of eyes. The latter are southern forms, rarely found north of Iowa.

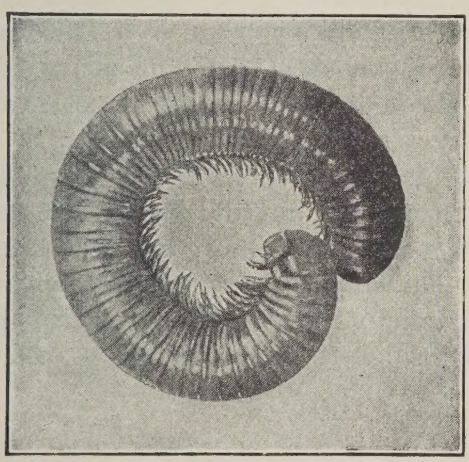


FIG. 113.—A millipede. (*Corwin and Corwin.*)

240. Myriapods are all terrestrial animals that prefer moist, dark places. They seem to avoid the light. They have been known for centuries, and have been feared on account of the dangerous bites which a few of them can give. Millipedes and

[1] Small spiders which cast a bit of web into the breeze from some support and often travel with it for quite a distance.

centipedes, which are the commonest forms, can usually be found in the woods beneath the bark and in the rotting wood of fallen tree trunks.

241. Since the following chapter deals with insects, we shall say only a few words here about them, although they are an important class of the arthropods.

The insect world is as varied and interesting as it is important. Insects possess a head, a thorax, and an abdomen. They have both simple and compound eyes, and six legs. Many of them, in fact the most of them, have two pairs of wings. Among the insects, especially the dragon flies, are the world's most expert fliers. The sexes are usually distinct. Although many species live in or near the water, insects are primarily land animals. They are the most numerous animals on earth and some of the most interesting, as you will learn in the following chapters.

Interesting Projects

1. Collect as many pictures of invertebrate animals as you can from various sources, and mount them with the name beneath each, on sheets of bristol board. At the top of each of seven sheets print the name of a phylum of invertebrates.
2. With the cooperation of your teacher, start a collection of preserved specimens representing all the principal groups of invertebrates, properly labeled. Enlist the cooperation of the members of your class to bring in specimens. If your school already has such a collection, see what important groups, if any, are not represented, and might be collected by the members of your class. Or, start such a collection for your own.

Review

1. Is a spider an insect? Give reasons for your answer.
2. How are coral reefs formed?
3. Name some animals which can grow new body parts.
4. Tell the life history of the hookworm.
5. Describe the water vascular system of the echinoderms.
6. Why have oyster-men discontinued the practice of destroying starfishes by cutting them in two and throwing them back into the ocean?
7. Why do many mollusks need such good protection?
8. Tell one characteristic of each class of arthropods.

Define

adductor muscle
cephalothorax
ectoderm
endoderm
excurrent opening
gemmule
hermaphroditism
incurrent opening
invertebrate
mantle
mesogloea
mollusk
regeneration
spicule
symmetry
trachea
viscera

CHAPTER XVII

MANY REMARKABLE ADAPTATIONS ARE FOUND AMONG THE INSECTS

242. The boy or girl who starts out with an insect net, or with just keen eyes and an inquiring mind, has a vast amount of pleasure in store. Habits of life among the insects are so varied, instincts are so marvelously developed, and their adaptations are so numerous and so exquisitely adjusted to conditions, that a whole world of wonder awaits exploration.

FIG. 114.—Howard, Leland O. (1857–) for many years directed the efforts of American entomologists in their work of insect control.

243. What Is an Insect?—If you were told that a "bug is an insect but that an insect is not always a bug", you would want an explanation of such a peculiar statement. Many persons speak of all insects and of all insect-like creatures, including the spiders, as being bugs. But, as in classifying other animals, we find that an organism to be placed in the insect group must have certain well-defined characteristics. First, it must have three pairs of legs. Second, it must breathe by means of tubes extending throughout the body from holes, the **spiracles** (*spir'-ak-ls*), in the walls of the thorax and abdomen, these tubes being known as **tracheae** (*trā'ke-e*). And third, it must have three distinct body regions, a **head,** a **thorax,** and an **abdomen.** (*ab-dō'-men*).

244. The list of common orders, given below, will show that members of only one order of insects can truly be called **bugs.** Can you tell from the picture of the spider on page 191 why it cannot be included in the insect group?

245. Classification.—There are, necessarily, many orders of insects because there are so many different kinds of insects. We shall study only a few of the most important. If some of the insects you have found do not find a place in one of the orders below, look in a book that specializes in insect study.

246. You might be able to find an insect that has never been classified before. That would be a rare scientific achievement and a high honor for any high school boy or girl. Probably not all of the insects will be classified for many years to come, there are so many of them.

Order	Pronounciation	Representatives
Lepidoptera	Lep-e-dop′-ter-ah	Butterflies and moths.
Coleoptera	Col-le-op′-ter-ah	Beetles
Diptera	Dip′-ter-ah	Flies and mosquitoes.
Orthoptera	Or-thop′-ter-ah	Grasshoppers and katydids
Hymenoptera	Hy-men-op′-ter-ah	Bees, ants, and wasps.
Homoptera	Ho-mop′-ter-ah	Cicadas, plant lice, and scale-insects.
Suctoria	Suk-to′-re-ah	Lice
Hemiptera	Hem-ip′-ter-ah	True bugs,—Giant water-bug, water boatman, water strider, squash-bug.

247. Lepidoptera.—Probably the most interesting members of the insect group, from the standpoint of the amateur collector, are the butterflies and moths. The intricate designs and beautiful colors of many of them are a source of admiration. From the time that the first bedraggled Mourning Cloak butterfly flutters uncertainly from its place of hibernation under the loose bark of a tree or other sheltered place, until the last group of Monarchs majestically wends its way to the south, there is a constant succession of beautiful forms to assist the birds and flowers in making this world the attractive place that it is.

248. For this attractiveness, however, we must pay a heavy price, because in the **larval stage,** many of them are so destructive. During this stage of rapid growth and frequent **molting** (shedding the outer covering), insects eat an enormous amount of food for animals of their size. When they are very numerous, they destroy vast quantities of field and garden crops as well as other kinds of plants.

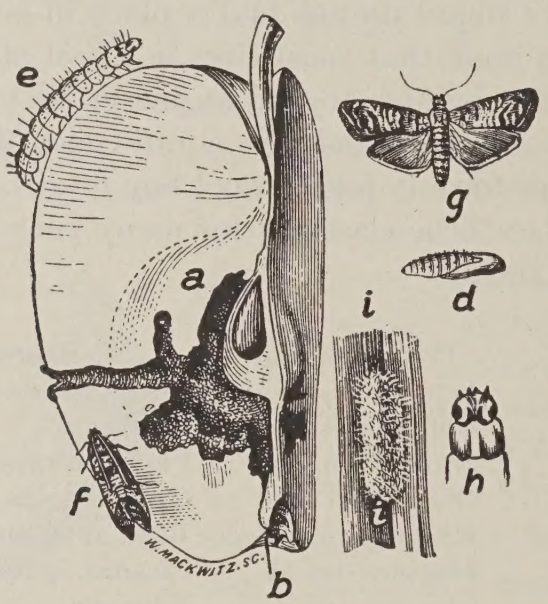


FIG. 115.—Codling moth, *a*, apple showing tunnel made by larva; *b*, where egg is laid; *e*, larva; *d*, pupa; *i*, cocoon; *h*, head of larva; *f*, *g*, mature moths. The larva enters the fruit at the time it is forming and, in feeding, burrows the familiar tunnels. It is the only cause of "wormy" apples. (*Holmes.*)

249. The caterpillar, or larval stage of the butterfly or moth, frequently looks so different from the adult that it is hard to see how one is derived from the other. When there is a larval stage and a **pupal stage** (when a cocoon or chrysalis is formed around the body), we say that the insect has **complete metamorphosis** (*met-ah-mor'-fo-sis*), or change of form. Some, like the grasshopper, are hatched in much the same form that they will have as adults, differing from the adults principally in size and in having no wings. These immature forms are known as **nymphs.** As there is no complete change of form, this kind of change is known as **incomplete metamorphosis.**

250. The Monarch butterfly is rightly named. A substance within the body which the birds find disagreeable to their taste, protects the insect so completely that, in spite of its rather conspicuous markings, it flies about with no attempt at concealment and with an independence characteristic of royalty.

251. These butterflies usually arrive in the north from the southern states some time in June. The females prefer the leaves of the milkweed plant on which to lay their eggs—hence

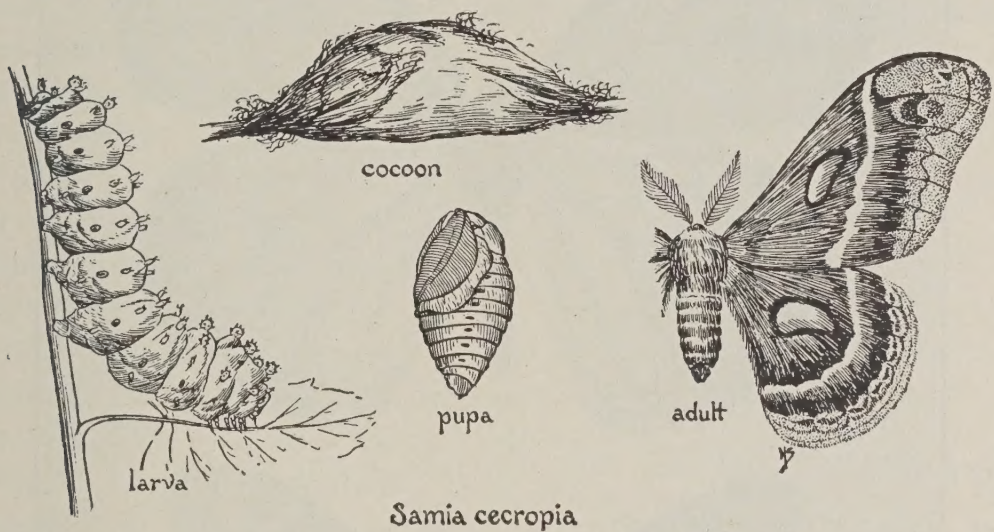


FIG. 116.—Life history of the Cecropia moth (Samia cecropia). Many butterflies and moths may be raised by collecting their cocoons or egg clusters and allowing them to hatch. (*Copyright by General Biological Supply House, Chicago.*)

the name "milkweed butterflies". After a few days, the number depending upon the temperature, the eggs hatch into larvae or caterpillars which molt three times, in the meantime feeding voraciously on the leaves of the milkweed, and growing rapidly. After a few days the striped caterpillar encloses itself in a beautiful light green chrysalis adorned with a semi-circle of gold beads and hangs suspended by a silken thread to one of the leaves, waiting to become an adult. Great internal changes are taking place during this stage. The wings form, also new legs. A different kind of mouth appears with a long, coiled structure called the **proboscis** (*pro-bos'-is*), for sucking nectar from the flowers. There is also a more complete nervous system.

252. When the pupa case first opens, the wings of the adult appear much crumpled. They had to be, in such a small

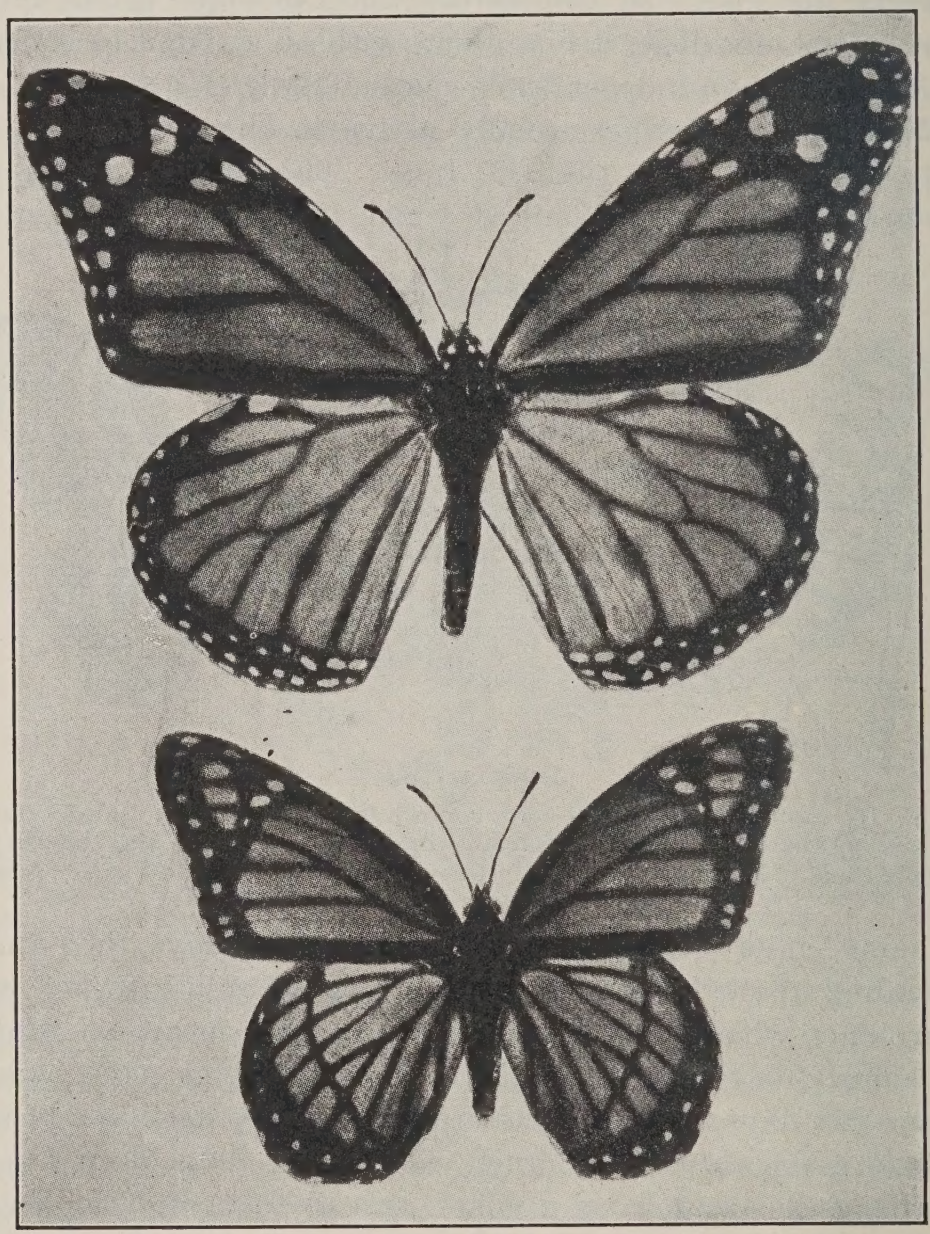


FIG. 117.—Except in size the Viceroy is similar to the Monarch in appearance. When one animal closely resembles another in this way, the condition is known as mimicry. (*After Lutz.*)

chrysalis. The butterfly rests quietly, spreading the wings out wider and wider by forcing air into them, and then trying

them gently, until after a few hours they are completely spread, dry and ready to bear its weight. Again it tries them, and now it has started on its first flight.

253. Have you ever seen the smaller butterfly which looks, in its colors and markings, so much like the Monarch? This is the Viceroy, and unless you were well acquainted with both of them you could readily mistake one for the other if you did not have them side by side. Look at Fig. 117 and see if you can find any other differences between them. This similarity between two species is known as **mimicry,** which means simply that one species resembles another.

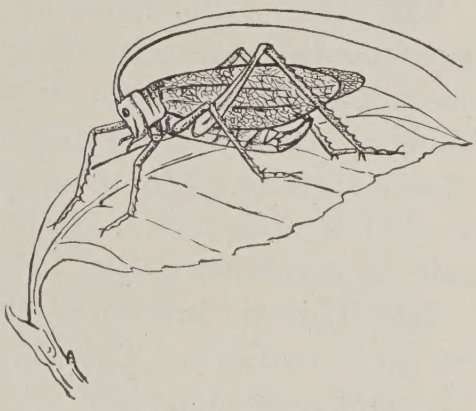


FIG. 118.—Resembling the green leaves where it makes its home, the katydid is very difficult to see. (*Corwin and Corwin.*)

254. Coloration.—Differences in colorings and markings among insects serve for a variety of purposes. Some of the insects secure their protection by concealing themselves. They do this by blending with the colors and objects of the background. An example of this is the way Katydid, shown in Fig. 118, resembles the green leaves. It would be very difficult for you to find this insect among the leaves of a tree. Others use concealing colors for the purpose of remaining hidden while they wait for their prey. This is known as **aggressive coloration.**

255. Then there is **warning** coloration, which we saw in the Monarch butterfly. Bees, hornets, and wasps use contrasting colors because they are protected by their stings.

256. Coleoptera.—How efficiently the members of this enormous group seem to be adapted to a variety of situations! There are the Tiger beetles, whose larvae prey upon other passing insects from a burrow in the ground. In the water the Diving beetles or Water-tigers are interestingly adapted in their method of trapping air under the hard outer wings so that it is possible for them to stay under water for a long time. Also living in

the water are the Whirligig beetles, which some of us have tried to capture as "lucky bugs".

257. You must have noticed how frequently the twinkling of fire-flies adds to the beauty of pleasant summer evenings. These, too, are beetles. But our pleasure may have been interrupted by the buzzing and bumping of the May beetles as they try to reach a light. The larvae of this latter form, often called "grubs", may destroy the roots of shrubs and are frequently very difficult to control.

258. Among the more destructive beetles, perhaps the best known is the potato beetle, which at times becomes very numerous. The larvae of the apple-tree borer likewise attack many kinds of trees besides the apple, boring tunnels through the woody sections of the trunk and branches, weakening the plant so that it is easier for the spores of disease-producing fungi to gain an entrance.

259. Thus we find the beetles successfully adapted to live under varied conditions. The adults of all species are able to fly. The larvae of many species and the adults of a few live under the ground, at least for a time. And we have noted how well certain kinds are adapted for living in the water. Like so many kinds of plants and animals which are successful, these Coleoptera have become so well adapted to their surroundings that protection from their enemies and the ability to obtain a food supply are assured.

260. Diptera.—A house fly, enlarged to the size of a horse, would indeed be a formidable-looking creature, but it might be less dangerous than it is now. Its feet are padded and soft, and its claw-like hooks are not strong. On the other hand, flies are so small and apparently so harmless that many persons do not realize the danger they may cause by the germ-laden dust that is on their bodies. The padded feet secrete a sticky substance which enables a fly to walk up a window pane or to hang, upside down, from a ceiling. This same sticky substance picks up quantities of dust and germs which are left on our food as the insect walks over it in search of food for itself.

261. The methods for eliminating this danger to the community are well known: screens to keep them out, fly paper and

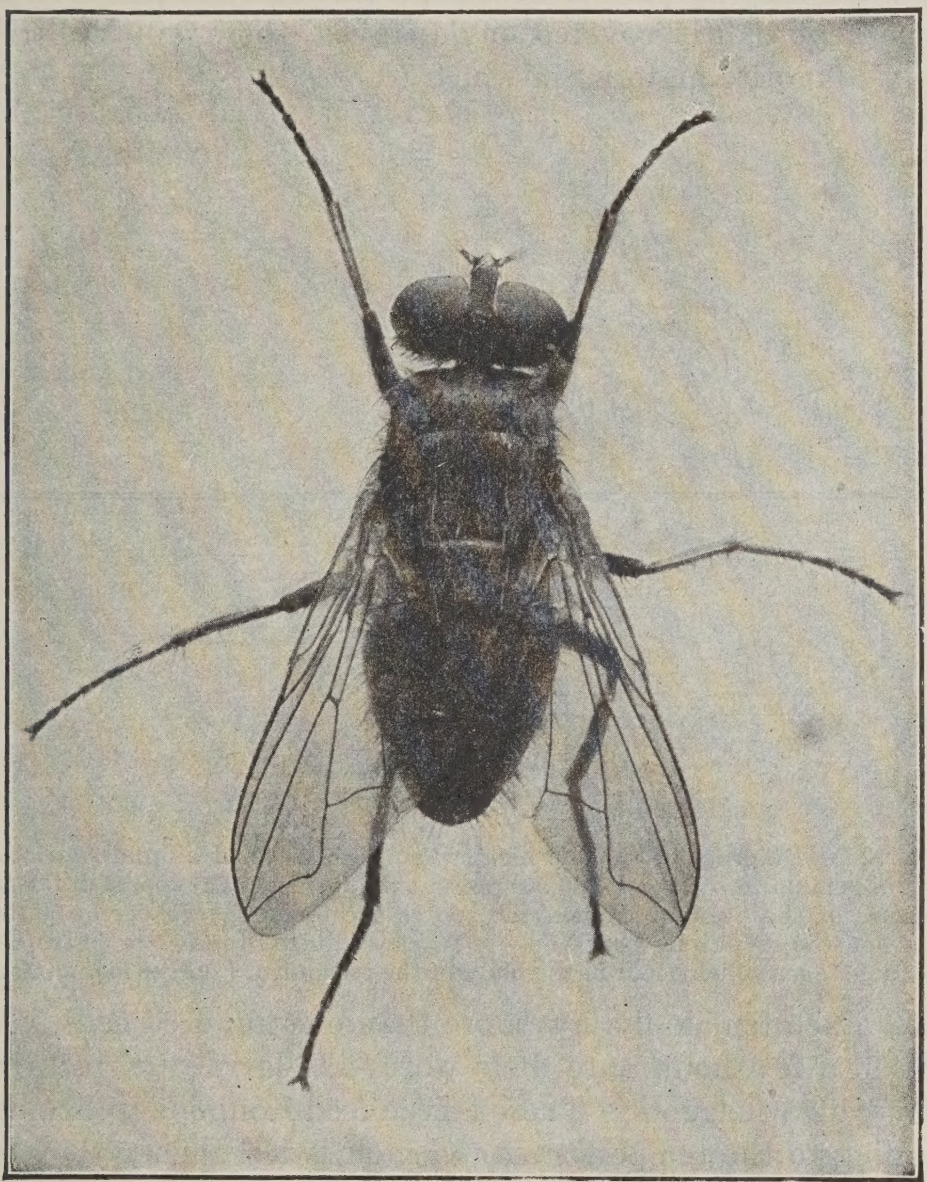


FIG. 119.—The sticky pads on the feet of the house fly pick up dust and germs. These germs come from the refuse on which the fly usually lays its eggs. Thus the fly that seems so harmless is actually a source of danger. (*From Reese, after Doane.*)

swatters to get rid of those that do get in. An even better method, so far as it is possible, is to abolish the places where they

breed. A fly always looks for some decaying organic material on which to lay its eggs, so that the young will have plenty of food when they hatch. Therefore, if garbage and piles of refuse can be kept tightly covered or destroyed, there will be little of the fly's favorite material in which to breed.

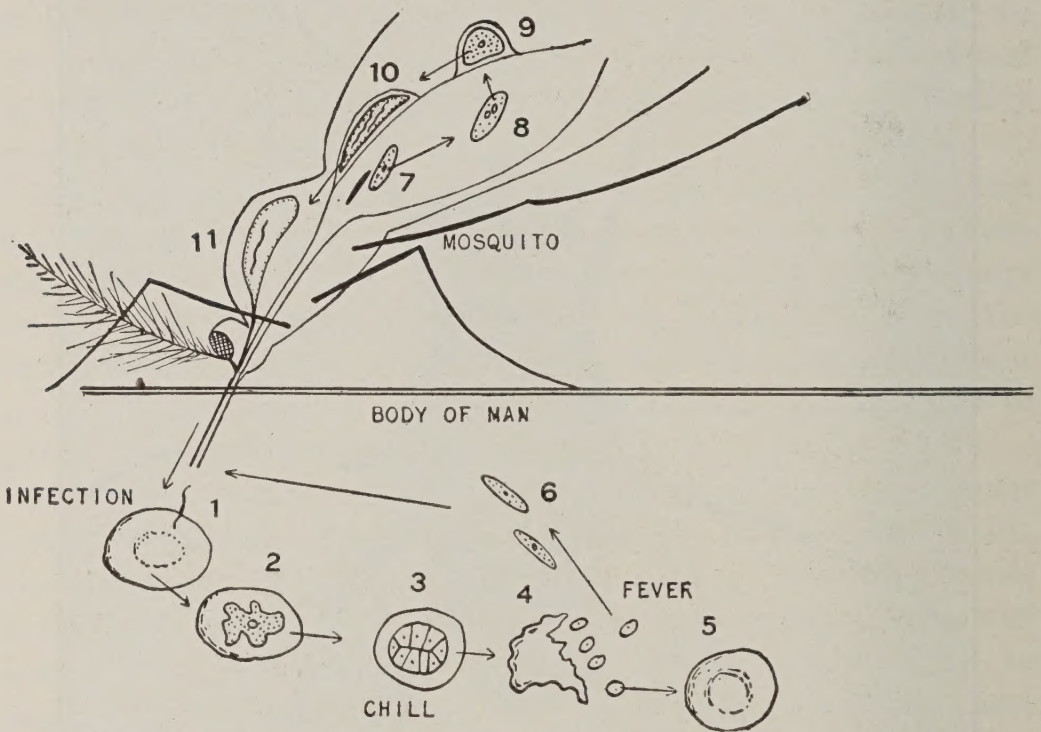


FIG. 120.—Diagram of the life history of the one-celled animal *Plasmodium* that causes malaria. Stages 1 to 5 represent the formation of spores in the blood corpuscles of the human. When the spores are forming, the person suffers a chill; when the corpuscles break open a fever results. Stages 7 to 11 represent the sexual stages which occur in the body of the mosquito. (*Atwood and Heiss.*)

262. Each female fly lays more than one hundred eggs, which hatch in a few hours into little worm-like larvae (*lar'-ve*), commonly called maggots. These larvae feed from one to five days, according to the temperature, and molt twice. Then they form a brown case around themselves and become pupae (*pu'-pe*). After about five days the adults emerge. Since each female lays eggs four times during the season, it is important to kill as many flies as possible when they first appear.

263. Probably the most notorious pest in the whole insect world is the mosquito. Lice and fleas are a source of great

annoyance at times, but mosquitoes being able to fly, are harder to avoid. If they were simply an annoyance because of their attempts to extract our blood, they would not be so serious a menace to health. But certain species of mosquitoes carry disease germs, hence they are dangerous.

264. Malaria and Yellow Fever Control.—It has been demonstrated again and again that malaria is carried by a species of mosquito known as Anopheles, while yellow fever is transferred from an infected person to a well person by a different kind of mosquito, the Aëdes (*ah-e′-dēz*).

The parasite that causes malaria has been found to be a **protozoan,** that is, a one-celled animal. This form has become so adapted for spending a part of its life history in a human host and part in a mosquito host that it may be transferred only in that way. Therefore it is possible to prevent its spread by keeping all malarial patients carefully screened from Anopheles mosquitoes.

265. As the eggs are laid in the water, where the larvae and pupae must develop, the draining of swamps and marshes prevents breeding. Sometimes the surface of the water is sprayed with oil which plugs the breathing tubes of the larvae or pupae and kills them. Occasionally some poison is used effectively.

The drug quinine has long been used as a preventive of malaria and in the treatment of it. However, it has a harmful effect on the nerves of the ears and consequently should be used only when necessary.

266. It has not been possible to determine the exact cause of yellow fever. No known power of microscopic magnification has been able to show a definite organism. The finest unglazed filters also fail to strain out any bacteria or protozoa. Therefore the cause is usually known as a **filterable virus** (*fil′-ter-a-bl vi′-rus*).

267. However, the lack of an exact knowledge of the cause of this disease has not made prevention of its spread impossible. As early as 1900 a special commission appointed by President McKinley and headed by Major Walter Reed proved that the

disease is mosquito-borne. This classic scientific work in Cuba made possible the building of the Panama Canal as well as the practical eradication of the disease from Havana by eliminating the carriers—the Aëdes mosquitoes.

268. It is fortunate for the people who live in the temperate zones that the mosquito which is common there, Culex, does not usually carry disease. It would be pleasant to be entirely rid

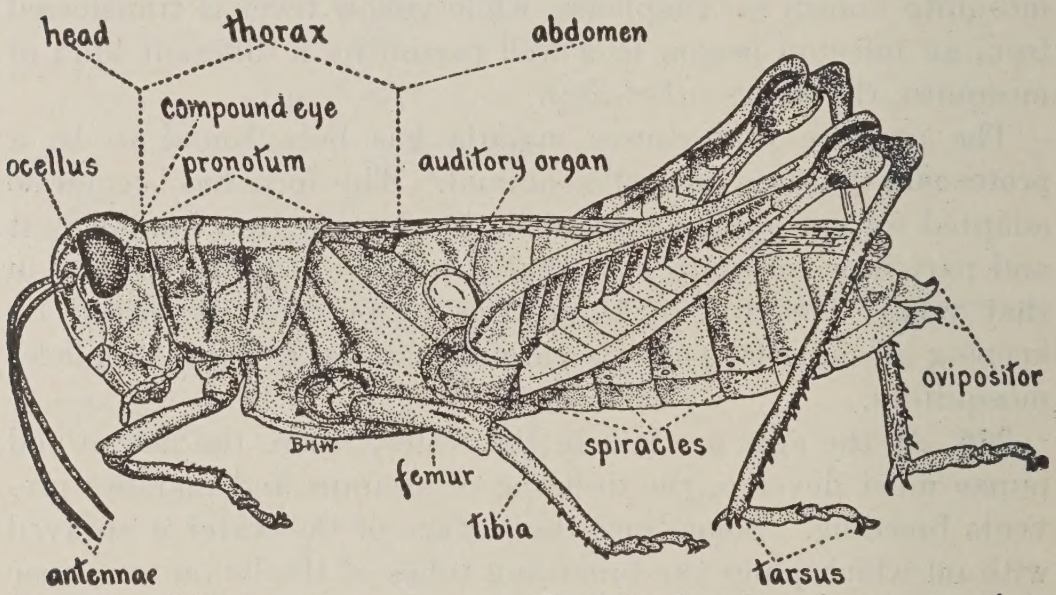


FIG. 121.—Side view of grasshopper. The left wings have been removed to show the auditory organ or "ear." (*Atwood and Heiss.*)

of this pest as we could be if it were possible to find all the pockets in the ground where many adults spend the winter.

269. Orthoptera.—Many centuries ago, according to the Bible, there were "plagues" of locusts in Egypt. Probably these locusts were grasshoppers. Certain sections of the United States are periodically afflicted with them, so seriously at times that the period is spoken of as a "grasshopper year", and great damage to crops results.

Orthos means "straight" and **ptera** means "wings." Have you noticed how long and straight the wings of the grasshopper are when folded against the sides of the body?

270. The mouth parts of this insect are adapted for cutting blades of grass by means of two **mandibles** or cutting jaws, which

move from side to side. Since the various kinds of grain are members of the grass family with long, flat, green leaves, the grasshopper feeds on them as readily as on grass itself. Then there are little finger-like projections known as **palps** which guide the food in over the mandibles to crush it. A long, slender structure, with projections on it, corresponds to our tongue in its action of guiding food.

FIG. 122.—Mouth-parts of a grasshopper. *m*, mandible; *max*, maxilla; *l*, labium; *p*, palps. (*Atwood and Heiss.*)

271. The body of the grasshopper, like that of all insects, is divided into three distinct parts; the head, the thorax, and the abdomen.

Two large **compound eyes,** each made up of hundreds of single eyes so placed that the whole structure projects slightly outward, enable the insect to perceive an approaching shadow from any direction. Then there are three tiny **simple** eyes between the two large compound eyes that enable the grasshopper to see objects close to it. The two long, slender feelers called **antennae** (*an-ten'-e*) are very sensitive organs of touch and smell.

272. The thorax has two pairs of **spiracles,** or openings, through which the insect breathes as it takes in and expels air from the tracheae. This thorax also has three pairs of legs attached to it. There are two pairs of **walking legs** and one pair of **jumping legs.** There are no wings when the young grasshopper or nymph first hatches, but two pairs develop when it becomes an adult. Can you tell how many different kinds of locomotion are provided for here?

Breathing takes place chiefly in the abdomen which has eight pairs of spiracles. On the first segment of the abdomen are two sac-like structures covered by membranes, by means of which the insect probably hears. They are called **auditory sacs.**

273. The last segment of the abdomen is modified, in the female, into an **ovipositor** (*o-ve-poz'-it-er*) for placing the twenty-

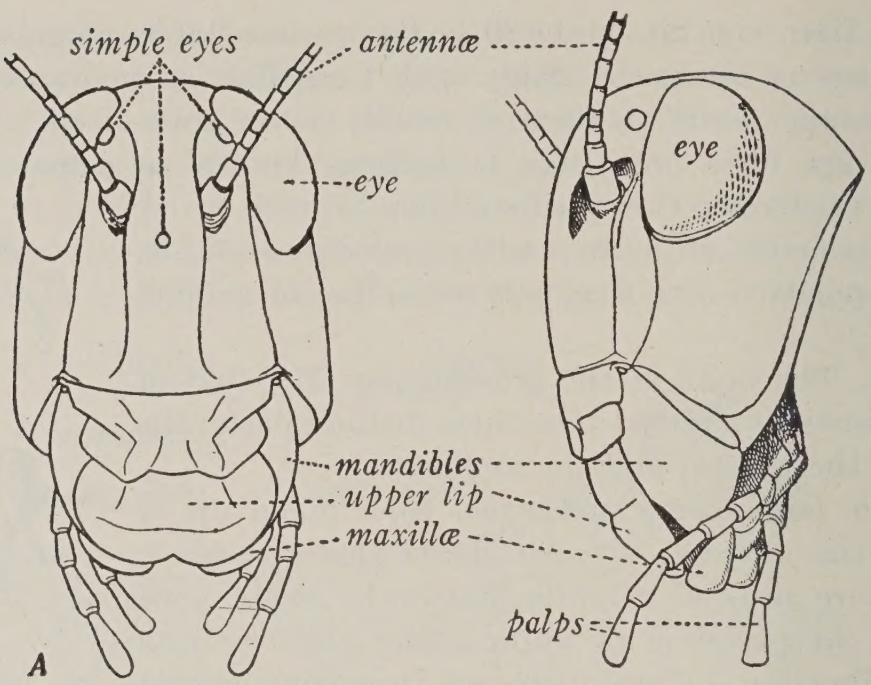


FIG. 123.—Front and side views of the head of a grasshopper. (*Atwood and Heiss.*)

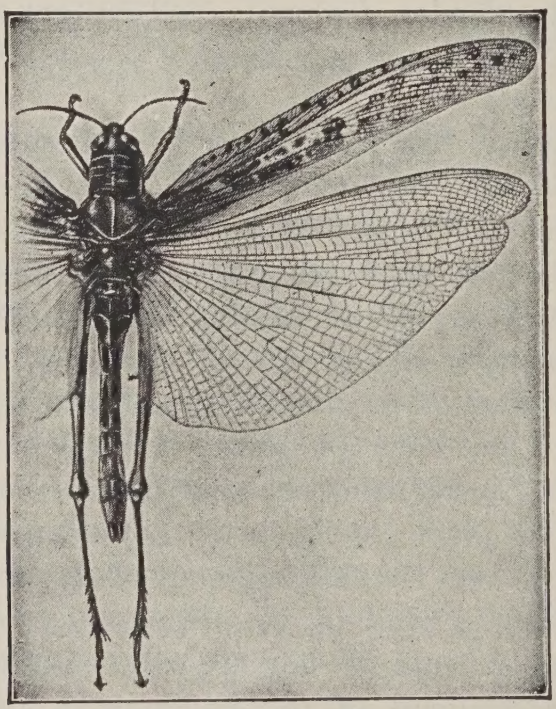


FIG. 124.—The wings of a grasshopper. When not in use the second wings are folded under the thicker first wings which protect them. (*Atwood and Heiss.*)

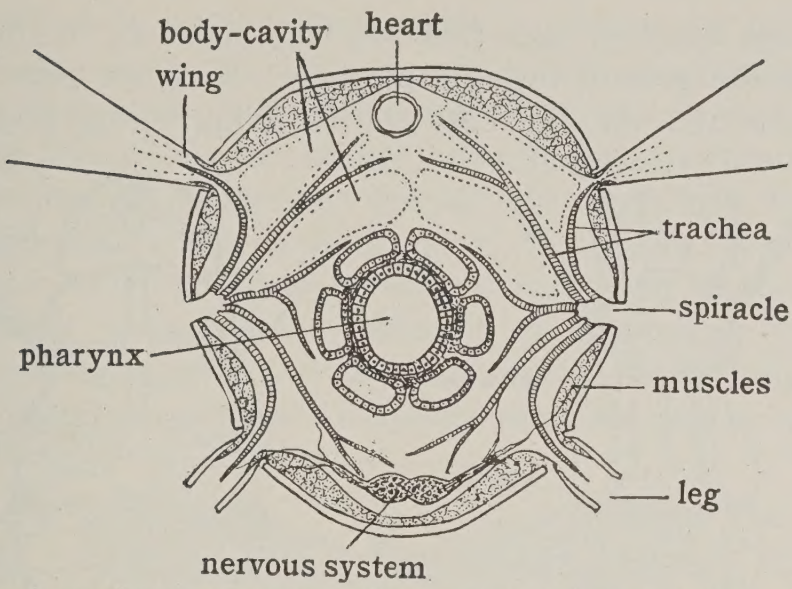


FIG. 125.—A grasshopper cut across the thorax region to show the arrangement of the organs of the thorax. (*Atwood and Heiss.*)

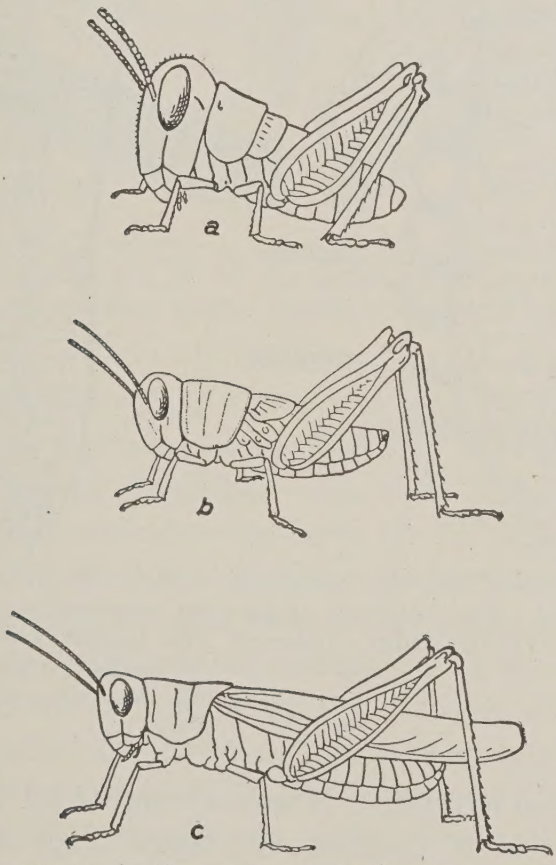


FIG. 126.—Three stages in the metamorphosis of a grasshopper. Note that the newly hatched grasshoppers are unable to fly. Wings appear after the nymph has molted six times. (*Holmes.*)

five to one hundred eggs that are laid each fall, in tiny holes made in the ground for this purpose. Here the eggs remain throughout the winter. Late the following spring they hatch

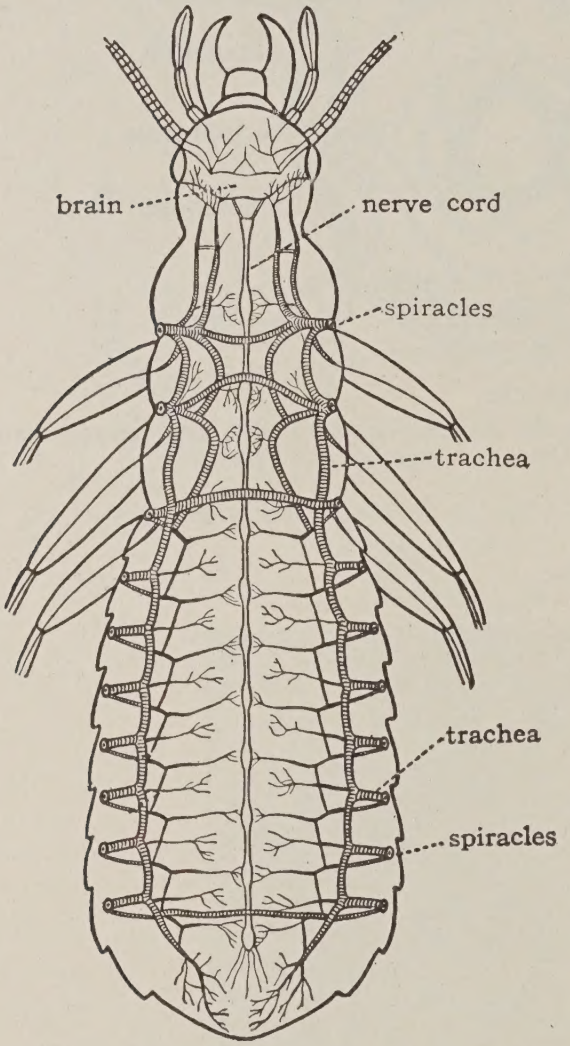


FIG. 127.—Diagram of the tracheal system of an insect. The branches of the system go to all parts of the body. (*Atwood and Heiss.*)

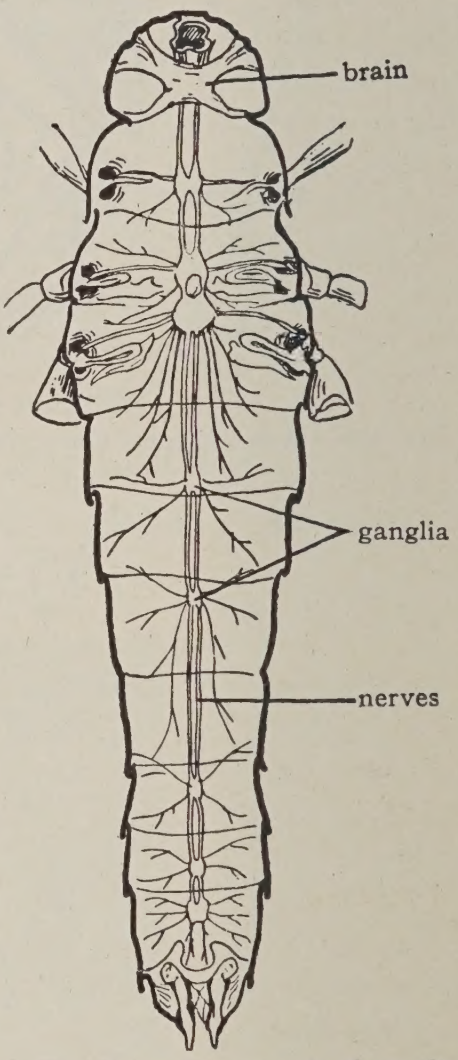


FIG. 128.—Diagram to show the nervous system of the grasshopper. The largest groups of nerve cells are in the parts of the body having the most work to do. (*Atwood and Heiss.*)

into tiny wingless nymphs. These nymphs feed voraciously and grow rapidly. After molting six times they become winged adults.

274. There is an old fable which contrasts the industrious habits of the ant in preparing for winter, with the careless habits of the grasshopper, which lives only from day to day with no apparent preparation for the inevitable, long winter ahead. Thus we have another instance of the fact that nature is often more concerned about the continuance of the *species* than of the *individual.* The grasshopper cannot withstand winter's cold, but the eggs, securely hidden away in the ground, are protected by being able to get rid of the water within them before being frozen (water expands when freezing), therefore they do not burst

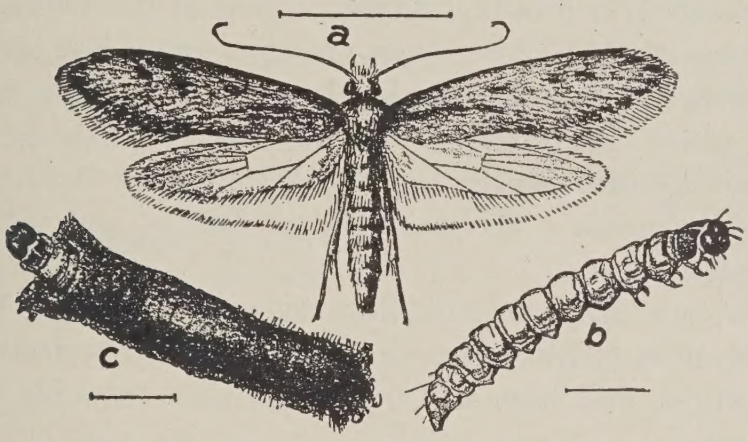


FIG. 129.—The clothes moth. *a*, adult; *b*, larva; *c*, larva in case. The lines represent the average length of the different stages. It is the larva, not the moth, that does the damage to the woolens or furs by eating them. (*From Holmes, after Riley.*)

when the temperature falls below the freezing point. Then, in the spring, water is absorbed so that they may hatch.

275. Man's Insect Enemies.—The fact that insects are very abundant is impressed upon us early in life. Some get into our homes, even when they are carefully protected, and destroy our food as the cockroaches and ants do, or make it unfit to eat, as the houseflies do. Others discourage our labors in the gardens with their persistence in attacking flowers and food plants. How often an otherwise pleasant trip fishing, hunting, or boating has been made uncomfortable by mosquitoes and black flies. Out-of-door parties frequently suffer from the same cause. Not only are our individual lives endangered, but the course of

development of mankind in general has felt the effects of the work of this group of animals. The plagues of Egypt and the delay in building the Panama Canal we have already mentioned. The helplessness of the all-conquering Romans before the attacks of the "gnats" (probably mosquitoes), so common in the swamps around Rome, and the devastating plagues of the Middle Ages, probably spread by fleas, all bear testimony of the age-old struggle with our insect enemies.

276. Although it is estimated that less than one percent of all insects are injurious to man's crops, even these destroy crops that are worth over a billion dollars a year in the United States, alone. Some of these destroyers are the cotton boll weevil, the codling moth, the San José scale, the corn borers, the army cut worm, the peach tree borer, the cabbage butterfly, the hessian fly, the Colorado potato beetle, the apple aphis, the Oriental moth, and the gypsy moth. What a long list this is, and yet it is far from complete.

However, we are not friendless in our struggle. We shall learn in the next chapter how certain other insects destroy some of our enemies, and how still others provide valuable products which we use.

Interesting Projects

1. Make a collecting net, a killing jar, and a mounting board according to the directions in a book on insects such as Lutz's "Field Book of Insects", published by G. P. Putnam's Sons.
2. Arrange in boxes according to their orders the insects you collect. Whenever possible give the name of the species.
3. Make drawings to show as many kinds of mimicry as you discover.

Review

1. Give the characteristics of each of the eight most important orders of insects.
2. Why is the larval stage of an insect usually the most destructive stage?
3. Give examples of insects having a complete metamorphosis and other examples of insects having an incomplete metamorphosis.
4. Describe the different types of coloration among insects, and state the purpose for which each is used.

5. Relate the story of man's conquest of malaria and yellow fever.
6. What are the similarities in structure between the grasshopper and the monarch butterfly? What are the differences in structure between these two insects?
7. Why are insects considered to be man's most important competitors for the supremacy of the world?
8. What are the differences between insects and all other kinds of animals?
9. Compare the communal life of any one kind of social insects with man's social activities.
10. What are some of the methods used to combat the destructive work of insects?

Define

abdomen
aggressive coloration
antenna
arthropod
auditory sac
complete metamorphosis
compound eye
filterable virus
incomplete metamorphosis
insect
mimicry
molt
nymph
ovipositor
palp
proboscis
pupa
simple eye
spiracle
thorax
warning coloration

CHAPTER XVIII

MAN HAS FOUND THE ACTIVITIES OF CERTAIN INSECTS TO BE OF GREAT VALUE TO HIMSELF

277. Included among the helpful insects are those which destroy certain insect enemies of man; form products which man has been able to appropriate for his own uses; and cross-pollinate flowers, thus making possible the production of many kinds of fruits. In other words, they are our friends because of circumstances and not because they choose to be.

FIG. 130.—The tents of the tent caterpillar should be burned early in the spring when the destructive larvae can be destroyed in the nest.

We have already noted how many complex activities insects are able to carry on—so intricate that intelligence seems essential. However, numerous experiments have shown that their activities are due to unreasoning instinct; that they fail to show evidence of thinking as we usually apply the term to the highest mammals, including man.

278. Hymenoptera.—The best known of the helpful insects which live in the temperate zone are the honey bees. Their principal product, honey, has been known for centuries and was at one time the most important source of sugar.

The social habits of bees have interested students of nature for many years, much having been written about them. The way

these insects work together, each individual contributing to the welfare of the group, and the various kinds of specialization for their work, are among the marvels of nature.

FIG. 131.—A swarm of bees. (*Atwood and Heiss.*)

279. There are usually three kinds of bees in a swarm. The largest is a completely developed female, the queen. She alone is able to lay eggs. All the other female bees, much smaller in size, are the workers and are not able to lay eggs. Then there are the thick-bodied drones or males, and except for the function of fertilizing the eggs, they are useless members of the colony. They are tolerated by the workers during the summer when food

is plentiful, but they are often killed by the workers in the fall when food becomes scarce.

280. Honey, wax, and a peculiar varnish-like substance, known as **propolis** (*prop'-o-lis*), are made by the worker bees.

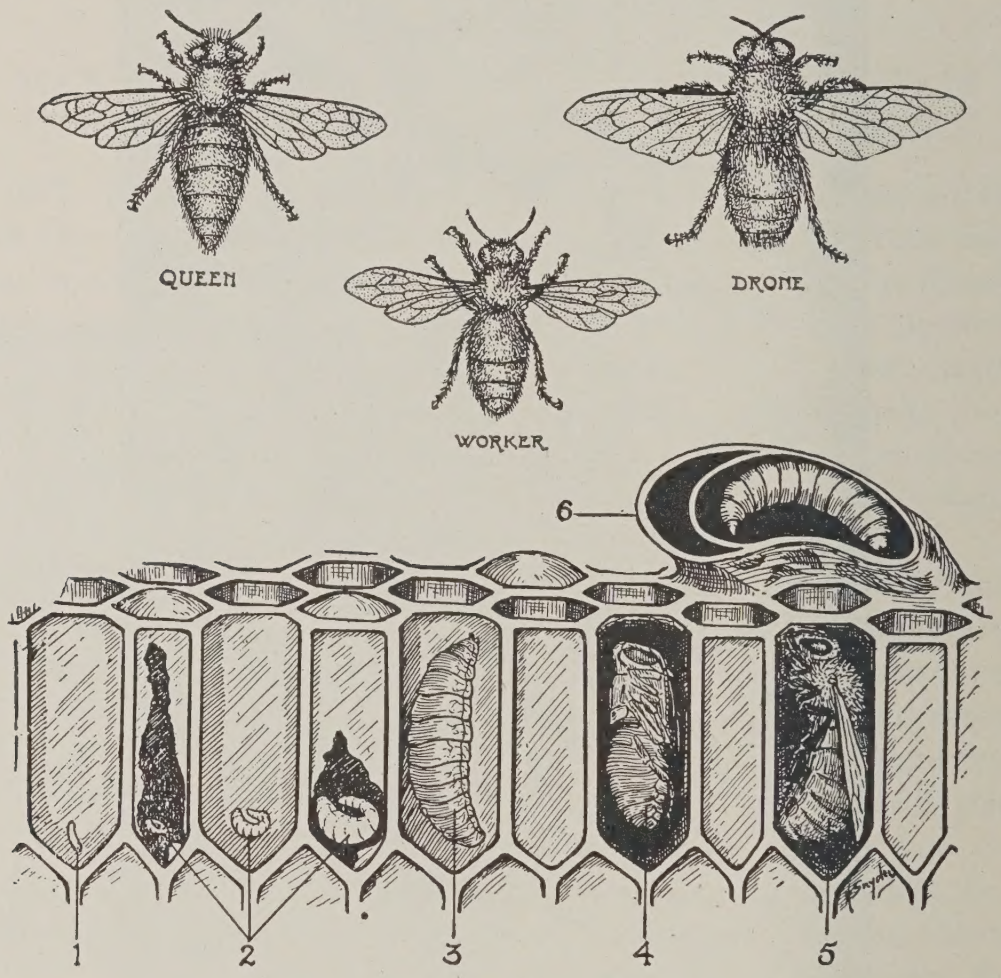


FIG. 132.—Each kind of bee is adapted to aid the whole colony. (*Copyright by General Biological Supply House, Chicago.*)

Honey is made in the crop of the bee, where the cane sugar of the nectar from the flowers is changed into grape sugar. This is stored in the comb within the nest to ripen, while the workers cause the excess water to evaporate by rapidly fanning it with their wings as they hover over it. Wax is secreted from the

abdominal segments of the bees after they have gorged themselves with honey. It is used to make the cylindrical cells of the comb (which become six-sided by pressure) where the honey is stored and the larvae are reared. Bee bread, which is a food substance made of pollen and saliva, is also stored in these cells.

281. Because of certain unfortunate experiences with bees or other stinging members of the hymenoptera, such as wasps or hornets, many persons are acquainted with their use of the sting. This structure, designed as an ovipositor (a device to deposit eggs), is adapted to be used for defense and occasionally for offense. There are two principal parts, barbed at the ends and enclosed within a sheath. When it is used for piercing the body of an unwelcome insect visitor, the barbed ends are readily pulled out through the more brittle covering. The human skin is more fibrous. Consequently the barbs hold, and the sting or ovipositor with some of the attached parts may remain when the insect leaves. We see from this that the popular idea that a bee can sting but once is not always true. If the bee successfully removes the sting, then it may be used again. The worker bees are equipped with this device although they do not lay eggs. The male bee has none and therefore cannot sting.

282. Besides producing the substances mentioned above, the workers also feed and wait on the queen, the larvae, and, occasionally, the drones. Some clean the hive of all foreign matter, while others fan the air with their wings to provide ventilation. Sometimes workers can be found which have actually worn out their wings during the summer season.

283. When more than one queen bee appears, there is usually a battle to see which shall be the surviving queen. Sometimes the older queen is prevented from fighting, and then, with some of the workers, she leaves the hive to establish a new colony. They usually go to a hollow tree in the woods. This flight is known as **swarming.** Not all of the causes of swarming are known. It is often very difficult for the bee keeper to tell when the colony is about to swarm, and sometimes the bees escape before their disappearance is even known.

284. Irreparable harm would result if the butterflies and moths, together with the bees should cease their work of cross-pollinating the flowers. This work is so important that often fruit growers keep hives of bees in the orchards during the blooming-period, not so much for their honey, which may never be taken, as to insure pollination and so, a more abundant crop of fruit.

285. Parasitic Insects.—Other good friends are the members of the Ichneumon (*ik-nu'-mon*) family, which usually deposit

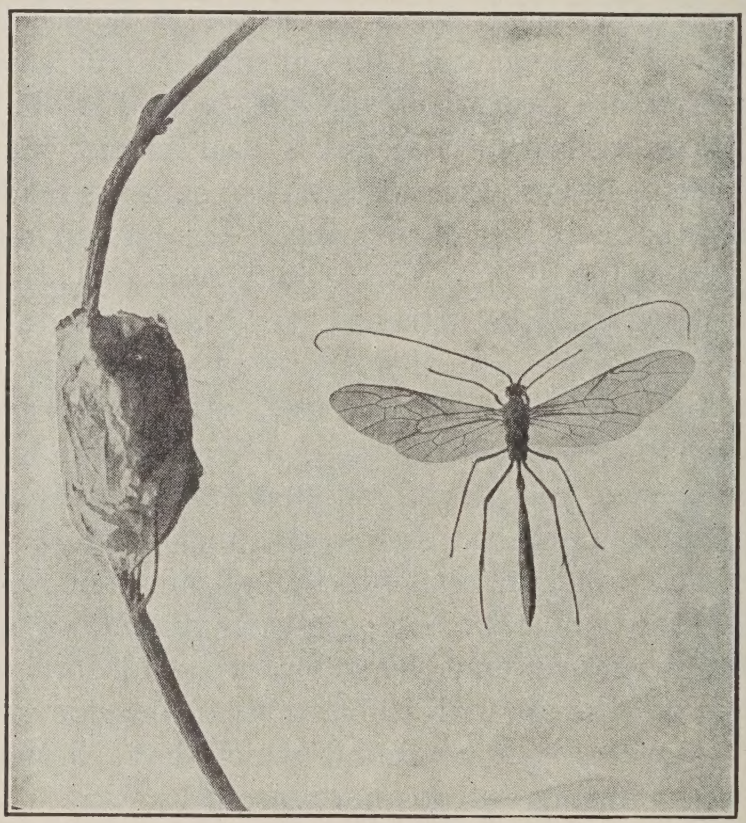


FIG. 133.—A cocoon of the lunar moth, and the ichneumon-fly which emerged from it. The adult lays its eggs in the bodies of the larvae of other insects. After hatching, the larvae of the ichneumon-fly feed on the larvae in which they live, thus destroying them. For this reason the ichneumon-fly is an aid to man in the control of harmful insects, especially the wood-boring varieties. (*Atwood.*)

their eggs in the bodies of the larvae of insects. After hatching, the larvae of these parasitic ichneumon "flies" destroy their host by feeding upon it.

You will see from Fig. 133 that they are grotesque-looking insects. The formidable structure at the end of the abdomen

is an ovipositor, and need not be feared as a sting—it is not used in that way.

286. Wood-boring larvae are frequently the victims of certain members of this parasitic group. It is difficult to understand how the female ichneumon can project such a delicate ovipositor through wood to the narrow tunnel which is being formed by the wood-boring larva. It is another example of the highly efficient adaptations, especially common among insects.

FIG. 134.—Ladybird beetle. This beetle is sometimes raised in enormous numbers in laboratories to be released as an aid to man in his control of the destructive plant lice. (*Corwin and Corwin.*)

287. Another common parasitic insect is the lady-bird beetle. This species is raised in large quantities and shipped to fruit and vegetable growers, especially in the western states, to aid in checking plant lice and scale insects. The lady-bird beetles devour both the larvae and the adults of these pests.

There are many different kinds of parasitic insects which feed on other living insects. It has been estimated that one-half of all the insects are parasitic on others—fortunately for us.

288. The Silkworm.—Then, helping us in a different way, we have the silkworms, or larvae, which produce a fiber for building their cocoons. This fiber can be used for making fabrics of such beauty that man, with all his resources, has not been able to equal them by any other process.

Silk making, one of the oldest industries in the world, is credited to empress Si-ling, the wife of Huang-ti (2640 B.C.) emperor of China. The fiber, which is continuous, must be wound off the cocoon before the adult emerges and breaks it in many places. The fiber is very small, about fifty being required to make a thread of sewing silk of ordinary size.

289. The Ants.—These insects, also members of the order hymenoptera, are not our friends, as are those which we have just been considering. In fact, they are often our enemies, especially in the south, when they may become serious pests. But if

we study their normal social activities, we find much to interest and entertain us. In the latter sense, then, we may include them here.

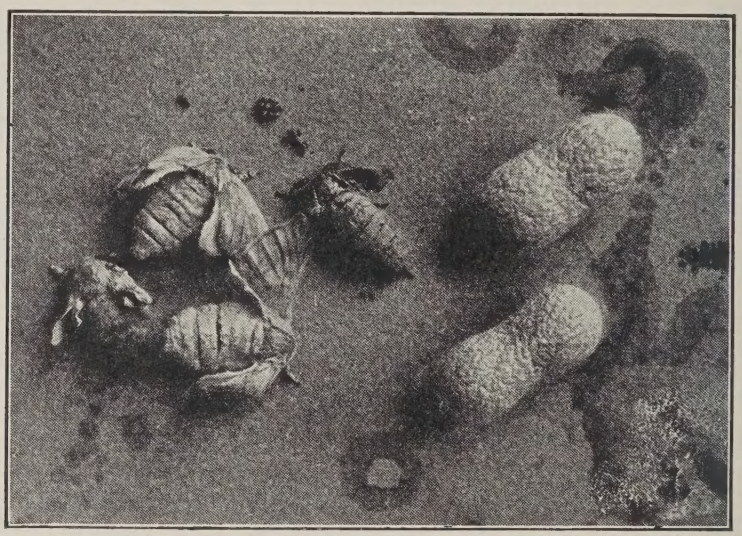


FIG. 135.—Silk-worm moth, eggs, and cocoons. (*Holmes.*)

Ants have many unusual and interesting ways, some of which are much like our own. Perhaps their activity most resembling that of humans is the way they keep aphids or plant lice as prisoners for the sweetish secretion they produce, of which the

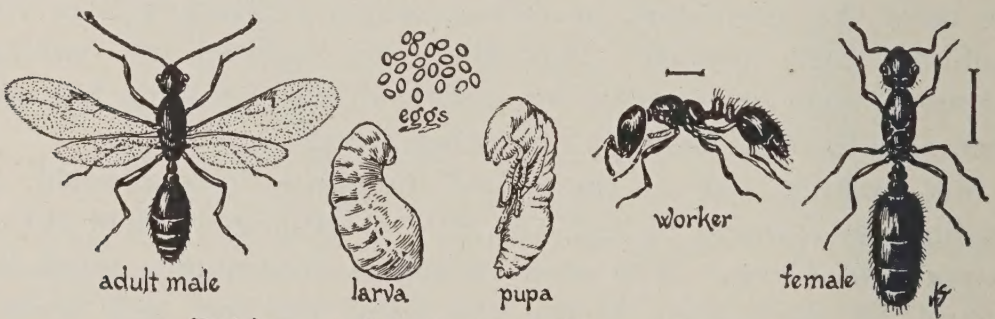


FIG. 136.—The social habits of these insects may be made an interesting study. (*Copyright by General Biological Supply House, Chicago.*)

ants are very fond. This activity may be compared directly to man's care of cows for their milk. Certain species of aphids are carefully protected by the ants in their homes under ground

during the winter. Then, in the spring, they are placed on the roots of tender young plants where they can feed while being guarded from enemies by their ant masters.

290. The Development of Insect Life.—All insects, as we have seen, are well adapted for their struggle for existence. Geologists tell us that in the Carboniferous Age, when the great masses of vegetation were laying a foundation for our modern coal fields, long ages before man made his appearance, the insects were thriving successfully. Many species were larger than they are now. Cockroaches were larger than a man's finger. Another kind of insect that looked like our modern dragon fly had a wing spread of thirty inches. These insects were not able to compete with the vertebrates in size. So insects continued to be abundant numerically, developed a less conspicuous size, and fitted into the smaller, but very important places in the general scheme of things.

With their efficiently constructed bodies and their marvelously developed instincts, they are becoming effective competitors for our supremacy of the earth. For this reason, some scientists predict that they will be in existence long after man himself will have become extinct.

291. Methods of Insect Control.—In contrast to this rather discouraging prophecy, we have the fact that man's intelligence has contributed many effective methods of control. Each year sees new chemicals and devices for protecting food crops against the ravages of his insect enemies in the field. For example, within recent years, because insects are subject to disease, just as all other organisms are, certain bacteria and fungi which destroy insect life have been employed. These disease-producing organisms are developed under carefully controlled conditions. After tests have determined that nothing will be harmed except the insect enemy concerned, they are raised in large numbers. Then some of the offending insects are caught, infected artificially, and released. Soon, if the procedure is successful, an epidemic is spread, which may be very destructive to insect life and far-reaching in its benefits to mankind.

292. During the transportation of food products from one country to another, insect pests are occasionally introduced, although elaborate precautions are taken to prevent it. Therefore we can expect to see man's ingenuity tried many times in the future. If this kind of work appeals to you, it must be evident

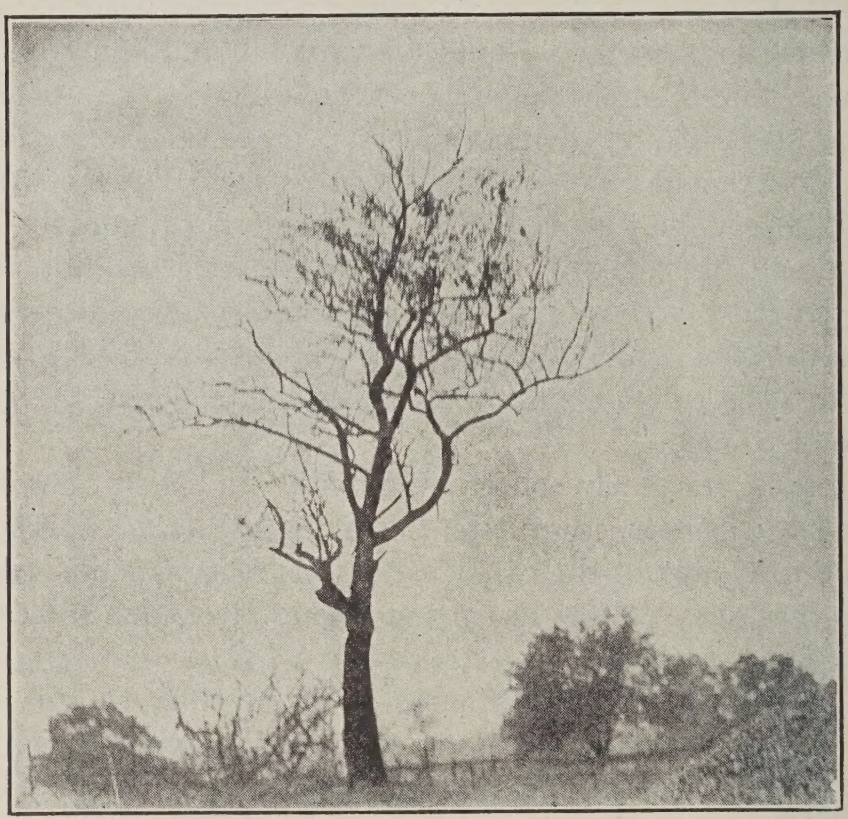


FIG. 137.—An apple tree dying because it has become badly infested with the San José scale. (*Atwood.*)

that the opportunities for such work, besides being inviting, are practically limitless.

Interesting Projects

If it is possible to visit the agricultural department of your state university, make inquiries concerning recently devised methods for controlling insect pests.

Review

1. What social activities of insects are also carried on by human beings in your town or city?

2. How could it be proved that the activities carried on by insects are instinctive, and not guided by reason?
3. Name several different insects which are helpful to man. In what ways is each one helpful?

Self-testing Exercise

There are three kinds of bees in a swarm. The largest of these is the (1) _____ which is a perfect female. All the other female bees are the (2) _____. The males are known as (3) _____. Bees make three kinds of substances, (4) _____ from nectar, (5) _____, and a varnish-like substance called (6) _____. The sting of the bee is modified as an (7) _____ and is used for depositing eggs. When part of the swarm separates and leaves the hive to establish a new colony, the process is known as (8) _____. Many of the parasitic insects belong in the (9) _____ family. The (10) _____ beetles help to control plant lice and scale insects. The adult stage of the silkworm is a (11) _____. About (12) _____ fibers of the silkworm are required to make a thread of sewing silk of ordinary size. Insects are known to have been in existence a very long time, because their remains or (13) _____ are found in ancient rock formations.

Define

comb **parasitic insect** **swarming of bees**
propolis

CHAPTER XIX

IT IS DIFFICULT TO UNDERSTAND HOW THE VERTEBRATES DEVELOPED FROM THE INVERTEBRATES

293. To the student who is beginning the study of animal structure it may seem a little strange that the vertebrates developed from the invertebrates. We have always seen vertebrates, and we often take it for granted that the vertebrates have always been here. It seems to be a law of life that the simple shall come before the complex; that animal and plant forms of simple structure precede the ones made up of many intricate body parts, and the vertebrates, as a group, surely are much more complex in their make-up than are the invertebrates.

294. The Story of the Rocks.—Let us turn to the story of the rocks to see, according to their records, what animal forms were first to appear on the earth.

In the last part of Unit II, we learned something about fossils and how they may be formed. In the most ancient rocks which mark the early Archaeozoic (*ar-ke-o-zo′-ik*) Age, there are no fossils, for the time had not yet come for living things to appear. Then came the late Archaeozoic Age which lasted thousands of years, during which life probably began with such low and simple forms—probably plants first—as could endure the climate and the absence of those things which serve as food for the more complex organisms. Although no fossils except those of a few blue-green algae have yet been found, it is thought that the one-celled plants and animals lived at this time. Their bodies being very soft, and devoid of hard parts, would not be the kind to produce fossils. Then came the early Proterozoic (*prot-er-o-zo′-ik*) period, the rocks of which show the spicules

of simple sponges and the remains of algae. In the late Proterozoic period we find remains of bacteria, algae, and tubes made by the marine worms. Simple as these are, they show a distinct advance in the evolution of certain species. The following period, the Palaeozoic (*pā-le-o-zo′-ik*) shows further advance in the development of living things. In the early part of this period the rocks show fossils of mollusks, arthropods and a few of the other invertebrates, but as yet not a single vertebrate. During the middle of this period the land plants, corals, worms, the first fishes (one species attained a length of twenty feet), the amphibians and a very few simple reptiles appeared.

We need not read the story of the rocks further to discover that according to the record the vertebrates did not appear on the earth until long after many kinds of the invertebrates were already here.

Fig. 138.—Many invertebrates, like the spider, have several pairs of appendages; others have none whatever. (*Corwin and Corwin.*)

295. How the Two Main Groups Differ.—Let us pause at this point to ask ourselves how the vertebrates differ from the invertebrates. As a group, the invertebrates are more elementary, and the various systems are not so highly organized as those of the vertebrates. On the whole the invertebrates do not possess the degree of specialization that we shall see in the vertebrate groups. The most distinguishing characteristic of the vertebrates is the spinal column, composed of vertebrae, (frequently spoken of as the "back bone," although this term is a rather inexact one).

296. A still further difference between the two main groups is the arrangement of body parts. Someone has said that a vertebrate is "an inverted invertebrate." This statement needs some explanation. Among the lower animals, the nervous system, when present, is, for the most part, located in the ventral part of the body, below the food tube. The blood system as a whole is above the food tube, though not entirely so. The appendages for the most part are attached fairly low down on

the ventral side of the body. All this is reversed in the vertebrates. The nervous system here is dorsal, nearer the back. The heart is ventral. The appendages are also attached to bony girdles, which, as a rule, are dorsal. Just what the advantage is in this radical change we do not know. The fact remains, as the accompanying diagrams show, that the general location of body parts in these two main groups is exactly opposite.

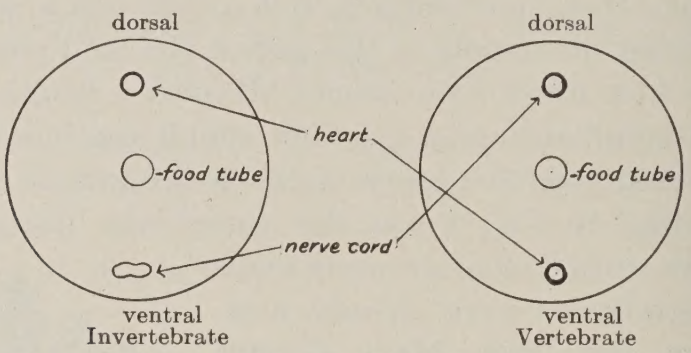


FIG. 139.—Diagram to show why the vertebrate is sometimes called an "inverted invertebrate."

297. Before beginning our study of the fishes as the first group of vertebrates, we might well ask, if for no other reason than that we, ourselves, are vertebrates, "Just what is a vertebrate, anyway?"

A vertebrate is any animal which possesses (1) a vertebral column ("spinal column" or "backbone")—always preceded by a notochord (*no'-to-kord*); (2) gill slits, either permanent or present during some period of development; (3) a well-developed tubular nervous system including a relatively large brain, and a spinal cord above the digestive tract; (4) and, usually, two pairs of appendages, such as legs, fins, wings, or arms.

Let us see just what these characteristics really mean so that we can apply them as a sort of yardstick to any new form of animal life that we may find. When we have decided whether any animal is a vertebrate or an invertebrate we have taken the first step in its classification.

298. *Vertebral Column.*—You have perhaps noticed the little bony "spools" in canned salmon or other fishes. Each of these

is a **vertebra.** The whole chain of them lying, as it does, along the back, allows more freedom of movement than one continuous and solid backbone possibly could allow. These vertebrae, however, are not always the basis of the supporting structures of the body, even in the higher animals. If you were to study the very young fish, or other vertebrate, while the body was being formed, before the time of birth or hatching, you would discover no vertebrae at all, but, instead, between the spinal cord and food tube, a cartilaginous rod. This is known as the **notochord.** Every vertebrate, which of course includes you and me, has one of these at some period of its development. A few primitive fish-like or worm-like vertebrates, little known except to the biologist, have a notochord throughout life, never having vertebrae or a "backbone." In the higher vertebrates, when the vertebrae start to replace the notochord, cartilage invades and pinches off portions which later become fused and solidified as parts of the vertebrae.

The vertebral column forms the basis of all the skeletal structures which differ from those of the invertebrate such as the crayfish or insect, principally in being a living part of the organism. In the invertebrate, as we have noted previously, the exo-skeleton is of hard, non-living materials which are deposited on the surface of the body.

299. *Gill Slits.*—Fishes, especially, have in the sides of the neck region, cuts or slits known as **gill slits** which may readily be seen. You may not know, however, that every vertebrate had gill slits at some time while the body was being built. Useless as aids in breathing, in all air-breathing vertebrates, they nevertheless show an interesting relationship among all vertebrates.

300. *Two Pairs of Appendages.*—You know that a bird has one pair of legs and one pair of wings, hence **two pairs of appendages.** The fish, likewise, has two pairs of fins besides the other single ones; and, in one form or another, nearly every vertebrate has two pairs of appendages. Of course snakes seem to be an exception, but, even here, if we will examine the skeleton of the

boa constrictor we shall find traces of the two pairs, although they are poorly developed.

301. *Nervous System.*—Among the higher invertebrates we find that the central nervous system consists of a nerve cord which lies beneath the digestive tract except at the anterior end. Here after branching to encircle the tract, it forms the brain, above. The brain of the vertebrate is in a similar position, but the spinal cord (which is actually not a cord but a tube) lies in the neural canal which is formed by the consecutive series of

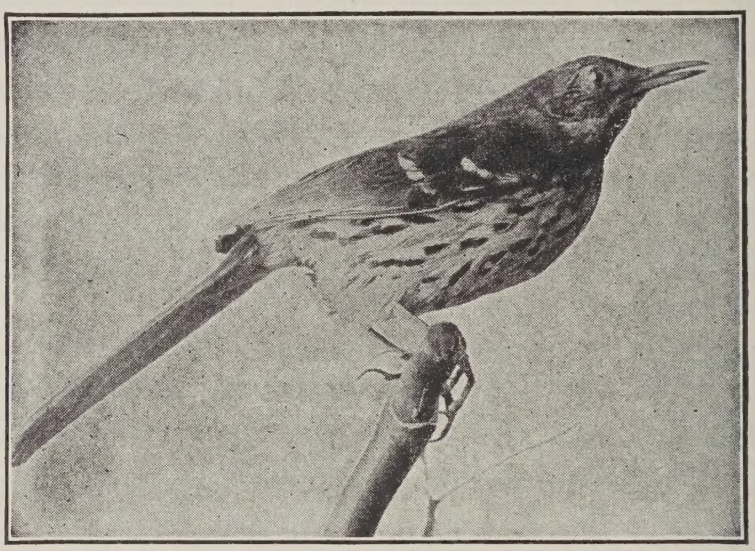


FIG. 140.—The brown Thrasher. Vertebrates possess two pairs of appendages. (Sometimes evident only in the embryo, as in snakes.) (*Atwood "Civic and Economic Biology."*)

holes through the vertebrae and which we have already found to be above the digestive tract.

The larger brain, especially of the higher vertebrates makes possible greater intelligence, more ability to choose, and less dependence on instinct and reflex action.

Such brain development has created in man a demand for homes, transportation, schools, business enterprises, and all that is included in the term "civilization."

302. The sense organs, which are specialized nerve endings, are very highly developed in animals that depend on them for securing food or for detecting the presence of enemies. We have

only to think of the keen hearing of the rabbit or fox, the quick scent of the deer, or the wonderful sight of the hawk to understand how far this kind of adaptation may go.

Interesting Projects

1. Visit any large natural history museum and ask to see some of the oldest fossils there. What are they like? Do they resemble any animals you have ever seen alive? Were they invertebrates or vertebrates?
2. Read in your library about the Devonian fishes. In what ways were they different from the fishes we know today? Were there other vertebrates besides fishes alive at that time? What did they feed on besides, perhaps, each other? Were there plenty of invertebrates on which they could feed?
3. It has been said that "a vertebrate is like an invertebrate, upside down". After a study of the diagram on page 192 explain the meaning of this statement.

Review

1. In what ways do vertebrates and invertebrates differ as to possessing any kind of a skeleton?
2. What four distinguishing characteristics do all vertebrates possess?
3. Name the five classes of vertebrates, in order, starting with those having the simplest structure.

Define

amphibia
appendages
archaeozoic age
coral
exoskeleton
gill slits
notochord
palaeozoic age
proterozoic age
reptiles
vertebra
vertebrate

CHAPTER XX

THE FISHES ARE THE SIMPLEST OF THE VERTEBRATES

303. Of all the vertebrates the simplest are the fishes. As everyone knows, all fishes are aquatic; that is, their lives are spent in the water. In some species, such as the dogfish, the skeleton is composed almost entirely of cartilage; more often, however, as in the salmon or perch—it is of bone. In all cases the skeleton is at first cartilaginous. In all higher fishes, however, it is later replaced by a bony skeleton.

The fish, like nearly all fast-moving objects, has a pointed body, the more easily to glide ahead with the least amount of resistance. Watch a living fish in a pool, in an aquarium, or even in a large jar of water. Notice its general shape and the ease with which it glides through the water. Can you tell how each kind of fin is used and whether they all function in the same way while the fish is swimming? Notice also how the fish breathes. Fishes get their oxygen from the water. Is this water taken in through the mouth or through the nostrils?

304. External Structure.—The body of the fish is composed of three parts, the head, the trunk, and the tail, although these parts are not clearly differentiated. The two front fins are known as the pectoral (*pek'-to-ral*) fins, because they are supported by the pectoral girdle. These correspond to which pair of our appendages? Similarly, the other two fins are termed pelvic or ventral fins. These two pairs are the balancers. The tail fin, known as the caudal fin, is the rudder and serves, as does the rudder on a motor boat, to keep the direction. The remaining fins, which are all single, aid as equalizers. Instead of being driven forward entirely by the caudal fin, the fish is propelled

ahead somewhat as a snake swims through the water, by the bending of its body from side to side. Each of the fins is stiffened by straight, bony structures known as fin rays. With the exception of the head, operculum, and fins, the whole body of most fishes is covered with scales. These point backward, thus enabling the fish to glide easily through the water. An interesting protective adaptation is the coating of mucus which covers the whole body of the fish. This mucus not only prevents the entrance of most parasites but also helps the fish in escap-

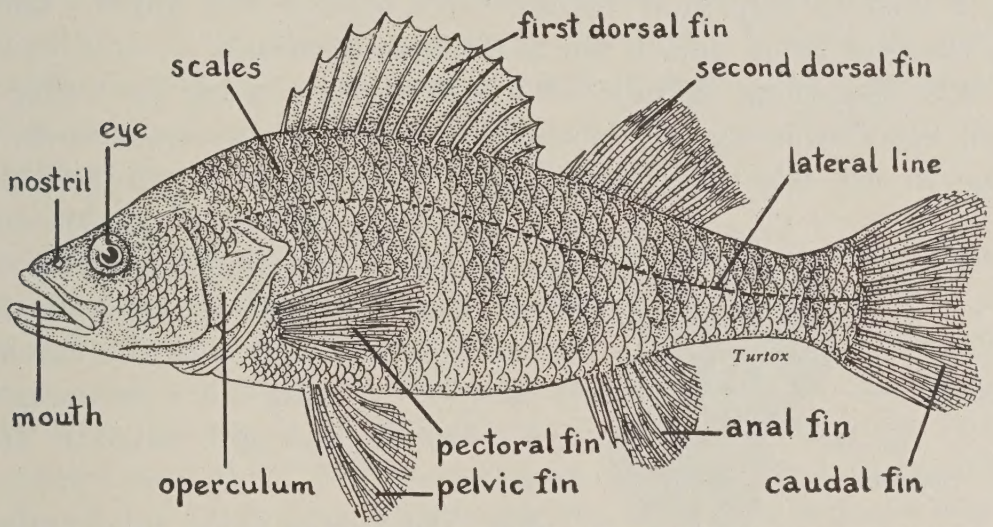


FIG. 141.—Side view of a fish. *(Copyright by General Biological Supply House Chicago.)*

ing from many of its enemies. You may have noticed, when attempting to pick up a live fish, how slippery it is.

305. The eyes of most fishes are large and are on each side of the head. This position allows great breadth of vision in the water without the turning of either the eyes or the body. The gills, lying in each side of the throat, are protected by a flat bony cover, the operculum. This, being open at the posterior edge, allows the water to escape easily from the gills by being lifted slightly as the water passes out.

306. The mouth of a fish serves several purposes. Placed as it is, at the front end of the body, it serves as a feeding, breathing, and protective organ. The teeth are round and pointed.

In many species they point backward into the mouth. Some species, such as the smelt, even have teeth on the tongue. Little chance has their live, wriggling prey to get away, once it is caught. The lateral line, mentioned later under "Nervous System" may easily be seen in most species as a thin row of depressions extending along each side of the body.

307. Although it is not an external structure, we should not fail to mention the swim bladder. This is a smooth-walled sac filled with gas, lying in the dorsal half of the body, which serves as a float to help buoy up the fish's body in the water. Only in the lung fishes does it aid at all in respiration.

308. Breathing Habits.—We sometimes remark how silly a fish looks, opening and closing its mouth. This appearance is due to the breathing movements. Breathing is accomplished as follows: the mouth is opened and the fish takes in a mouthful of water. Then the mouth is closed and the water is forced back into the throat. It escapes by going out over the gills and through the gill slits to the exterior.

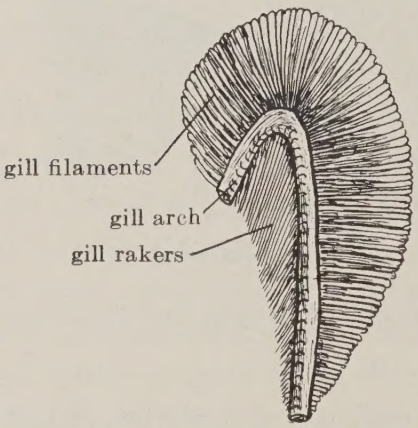


FIG. 142.—Gill of a fish.

309. The gills lie in the gill chamber in each side of the throat, there being the same number of gills in each chamber. Every gill has three parts. There is the cartilaginous or bony U-shaped **arch,** which is the frame-work and support of the gill. Then on the inner side of the bend of the gill arch are the teeth-like **gill rakers.** Around the outer part of the bend are the soft, sausage-shaped **gill filaments.**

310. The gill rakers vary a great deal in different species. In some species they just resemble blunt, bony teeth, while in others such as the perch they remind one of a fine-toothed comb. They are very important in some fishes, such as the menhaden, where they collect the greater part of the fish's food by simply straining the very tiny organisms out of the water which the fish

takes in. This food is then swallowed. In many other fishes the use of the rakers is much less important and therefore they are not so well developed.

311. But most important are the gill filaments. As was stated above, when seen under a lens they resemble tiny sausages. These are the breathing organs. They extract the oxygen from the water which the fish takes in; the filaments therefore must necessarily be very thin-walled. In a live fish you can easily see these bright red structures. They are filled with blood which is pumped around by the heart, a continuous stream of blood thus flowing through them all the time. In these filaments the blood and the outside water come in very close contact and it is not difficult for the necessary amount of oxygen to pass through the membranous walls into the blood stream, and so around the body.

312. Circulation.—The fish's heart is a model of simplicity. It consists of only one receiving chamber, the auricle, and one pumping chamber, the ventricle. At first this simple structure seems to be all that any vertebrate needs, since the function of the heart is to keep the blood stream flowing through the blood vessels;[1] and this "fish heart" as it is sometimes called, surely does that. But, as we shall learn later, this type of heart would not serve the needs of the human body.

313. After the blood is forced out of the heart it flows forward through an artery directly to the gills. Here this artery branches many times into tiny vessels, called capillaries, which supply each gill filament with blood. The carbon dioxide present in the blood is here exchanged for oxygen taken in from the water, the oxygenated blood being thus forced on into a larger blood vessel, the dorsal aorta, which supplies oxygen to the stomach, the intestines, the kidneys, and other organs. At the same time it takes in the waste gas, carbon dioxide, from the various parts of the body. The blood stream flows on, returns to the auricle

[1] In the fish this path is largely confined to the roof of the mouth, the tongue, the gills, the liver and the intestines. A much larger area than usual is supplied by the lymphatic (lim-fat'-ik) system.

and then to the ventricle, which contracts and thus sends the blood around again on its journey.

314. Excretion.—Excretion is the process by which the various wastes are removed from the body. In the last paragraph we saw how carbon dioxide is excreted from the gill filaments. The nitrogenous (*ni-troj'-en-us*) wastes are removed from the blood as it passes through the kidneys. From here these wastes pass on outward to the exterior. True excretion is the removal of those wastes which have once been a part of the body. The large intestine, therefore, is an organ of excretion only in so far as it discharges such wastes as the bile pigments from the liver. Obviously the removal of food residue is not true excretion.

315. Food-Getting.—While many species of fishes get at least a part of their food by means of the gill rakers, it is not true that all species do. As a class, fishes eat almost any kind of fleshy food, from earthworms, snails and insects, to smaller live fishes. The writer has in mind a certain trout which had a bird's foot in its stomach. But since food-getting is quite dependent upon the sense organs, which are the fish's means of locating the food, these organs will be discussed in the following paragraphs.

316. Nervous System.—The fish's nervous system is not all that is to be desired, although a small brain is present as well as a system of nerves. For the most part the sense organs are acute. Because of the fact that a fish has such a limited arterial system, the temperature of its body is usually from one to three degrees lower than that of the surface water.

317. Sense Organs. *Sight.*—Just how much can a fish see? Let us first consider the fish's environment. Because water at its clearest is rather dim and hazy,[1] the greater part of a fish's life, at least in the northern latitudes, is spent in darkness. For

[1] Several experiments, some of them requiring a sort of inverted periscope, have shown that the clearest ocean water looks hazy. "Objects at a distance of fifteen or twenty feet appear as though seen through a thin fog, while objects at a greater distance are less distinct and finally invisible." *The Senses and Learning of Fishes*, by Professor Jacob Reighard, pages 150–151.

nearly half the year the fish lives under a thick roof of ice and impacted snow, and when the surface is heated in summer, many fishes, to escape the heat, must seek a depth which is dark or nearly so. Therefore, it must be kept in mind that a fish's range of vision is a limited one.

318. On account of the location of the fish's eyes at each side of the head, each eye receives a different view. So, except for a

FIG. 143.—Fly fishing is an exciting sport. (*Courtesy Ontario Highway Department.*)

very narrow space directly in front[1] the animal sees two separate and usually two different views.

319. As to the ability of fishes to distinguish colors, it has been proved by numerous experiments that the common sunfish, the horned dace, and others can and do distinguish colors,[2] yet how clearly is uncertain. Numerous experiments in trout fishing with artificial flies have proved conclusively that trout will take red-colored flies when they will not take black ones, and vice versa;

[1] The area seen by both eyes is generally calculated to be limited to about 5 degrees directly in front of the fish.

[2] Professor Reighard of the University of Michigan reports an experiment in which the ends of an aquarium were illuminated, the one with blue and the other with red light. The fishes soon learned to discriminate between the red and the blue areas (one of which was associated with food) and continued to discriminate after the colors had been interchanged.

or that they will take white flies and refuse all others at one particular time of day and under the prevailing conditions of light and season.

320. *Hearing.*—The hearing of fishes is usually described as muffled. There are the usual structures of an inner ear, but there is no external ear, nor any canal to the outer world. It is now generally agreed that sounds originating in the air make little impression upon a fish's hearing, unless the sound waves are directed into the water; otherwise they are reflected off.[1] The reception of sounds is rather by pressure than by direct reception of sound waves as in the higher vertebrates. A jar upon the boat or a splash in the water sends the fish away like an arrow.

The lateral line, which you can see running along each side of the body, functions as a balancing organ and aids very materially as an amplifier of sounds. It is a part of the nervous system and is believed to be very sensitive to touch. It is so stimulated by water vibrations as to resemble a row of primitive ears.

321. *Smell.*—The sense of smell is now believed to be rather highly developed. It is used by some fishes in the finding of food, as illustrated by the blind fishes of the Mammoth Cave. This fact may account for their prejudice in favor of minnows, worms, grasshoppers, and flies as compared with artificial bait. Usually fishes have two small olfactory sacs, one on either side in front of the eye. As the sacs have no connection with the mouth, fishes are probably unable to scent objects held in the mouth.

322. *Touch.*—Probably their sense of touch is as keen as any of the senses, if one can judge by the lightning-like speed with which some of the game fishes spit out artificial bait, or jump when touched. It has been shown experimentally by Professor G. H. Parker that the dogfish possesses the sense of touch over the entire surface of its body, and the consensus of opinion is that *all* fishes have this sense highly developed and that it extends over the whole body.

[1] Refraction also occurs, but the ability of the fish to receive impressions in this way is limited to an angle of approximately 98 degrees directly above the fish.

323. *Taste.*—This sense is probably the least developed of any of the senses. The horned pouts possess small sense buds at the ends of their feelers. These sense buds are believed to be true organs of taste. Among fishes in general, organs of taste are

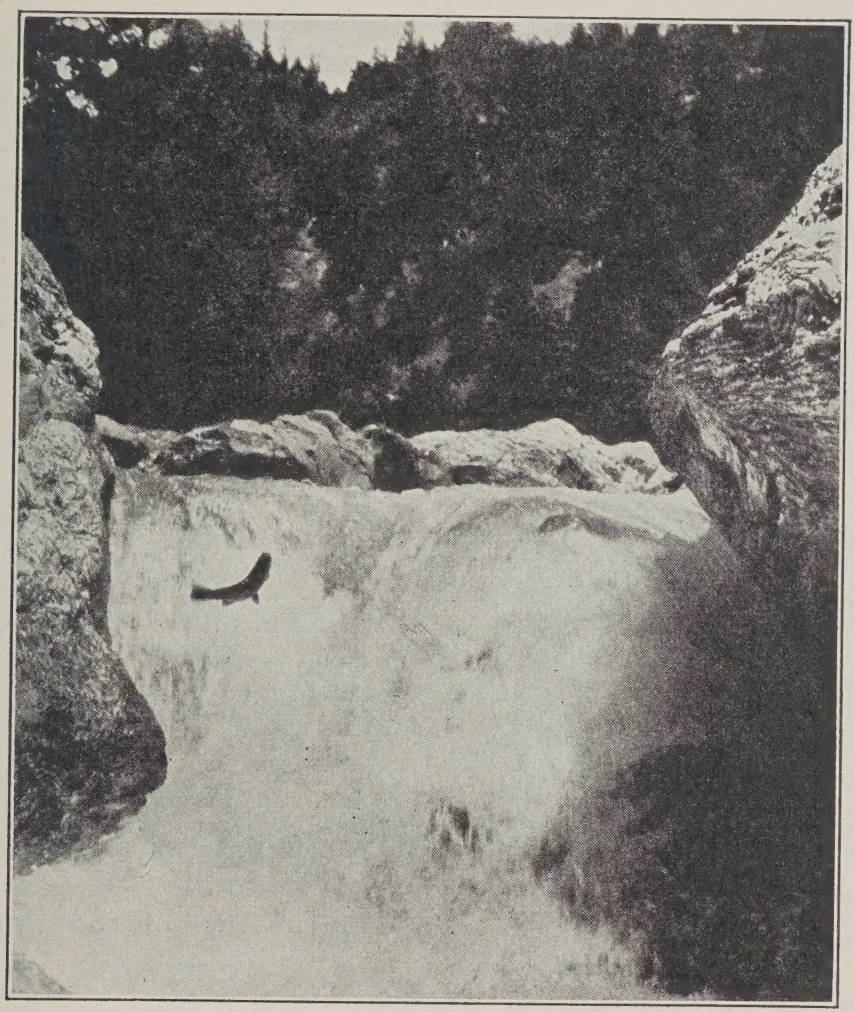


FIG. 144.—Trout jumping a falls while migrating. (*Corwin and Corwin.*)

lacking, although the distinction between the senses of touch and taste is generally regarded as one of degree rather than of kind.[1]

324. Life History.—One or two species of fishes bring forth their young alive. All the others reproduce by eggs and sperms. At certain times of the year, usually in the spring or fall, the eggs and sperm cells ripen and the fishes seek out their spawning

[1] Acknowledgment is here made for several suggestions as to sense organs, from the unpublished work of the late Professor Edwin W. Sanborn.

grounds. Many species show a decided preference for the small streams which are tributaries to the lakes and ponds where these fishes live. The migratory habits of some of our fishes such as salmon, trout, and smelts are very interesting and are easily observed if one can visit their spawning beds. The sight of millions of the fishes hurrying past each other in their mad rush upstream is a sight which, once seen, will not soon be forgotten.[1]

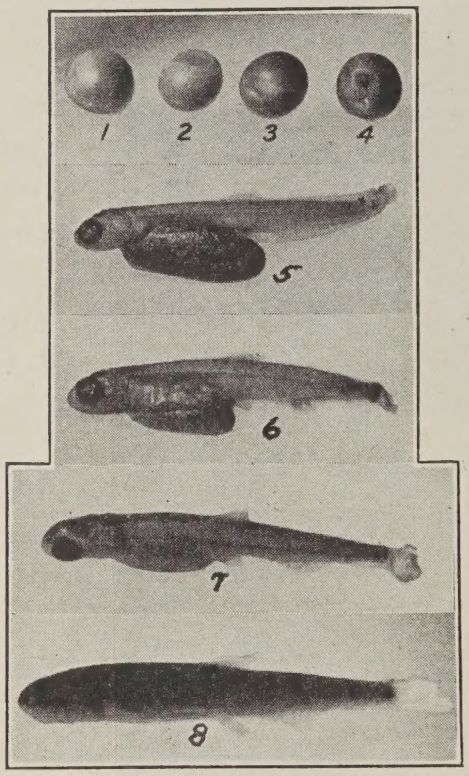


FIG. 145.—Development of a fish. 1–4, stages in the development of the fertilized egg. 5–7, stages in the development of the later embryo showing absorption of the yolk mass while the digestive system is developing. (*Canadian Government photo.*)

325. The eggs are laid in the water by the female fishes, and soon afterwards the male fishes swim over them giving out a fluid known as milt, which contains thousands of sperm cells. As these swim about, many of them come in contact with the eggs. When a sperm cell reaches an egg, it penetrates the egg and the nuclei of the two cells unite. This process is called **fertilization.** The fertilized egg then begins to develop and within a few weeks, the time depending on the species and the temperature of the water, it becomes a young fish. It is a peculiar little creature at first. It does not have much shape, as fishes go. But there is one structure which at once attracts our attention. It is the yolk sac—nature's storehouse of food for the tiny fish. The newly hatched fish feeds on this stored food until it has developed to the stage when it can take care of itself.

[1] David Starr Jordan has written a very interesting account of the migration of the salmon up the Columbia river. Probably it is in your school library. You will want to read it.

In most cases it has no protection. Even its own mother does not know it from the hundreds of other little **fry,** as the young fishes are called. Worse than that, either parent would gladly eat it if other food were scarce, for you know most fishes are

FIG. 146.—Scene in a fish hatchery. In these large jars and trays of running water the eggs and young fishes are fed and cared for until large enough to be liberated in the streams and lakes. (*Courtesy Ontario Highway Department.*)

cannibals.[1] It feeds and grows until it becomes an adult and the time comes for it, too, to spawn—up the same stream, perhaps, where it was hatched. And so the life cycle repeats itself.

326. Natural Obstacles to an Increase in the Numbers of Fishes.—We should remember that when the eggs are laid in the streams and lakes, they settle to the bottom in a mass, many of them never becoming fertilized. Then, too, so many fishes and

[1] The black bass are an exception, since they protect both their eggs and the tiny young although, when older, the young are readily eaten by the parents.

other aquatic animals feed upon these eggs that a large percentage of the fertilized eggs are never allowed to hatch. Except in the case of the stickleback, black bass, and a few other species, the eggs receive no protection. Even after the eggs do hatch, the young fry are eaten by water birds, by certain water insects, and by other fishes, so that although millions of eggs are produced, relatively few ever reach maturity.

327. The Fish Situation Today.—Years ago the demand for fish was not nearly so great as it is today. Nor had the recrea-

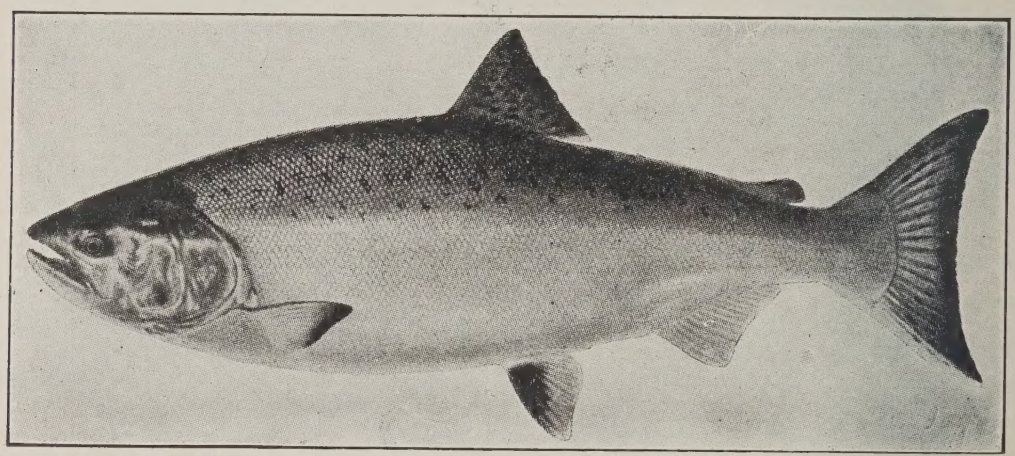


FIG. 147.—The king salmon, also called the chinook salmon. (*California Fish and Game Association.*)

tional value of angling approached anywhere near the place that it occupies now. Most species of fishes were breeding as rapidly as man and their other enemies were destroying them. In recent years, however, the tide has turned and today we are consuming nearly a million tons of fish annually in the United States alone.

The great salmon fisheries of the Pacific coast constitute our most valuable fishery. A large part of the product comes from Alaska where this industry gives employment to nearly 30,000 persons. The product from Alaska is now valued annually at more than $42,000,000. The control of this great industry is vested in the Department of Commerce and is administered by the Bureau of Fisheries. In order that this industry may be properly regulated, extensive studies have been carried on for a number of years. As a result it is probable that the life histories

of the several species of salmon and trout are better known than those of any of the other important food fishes.

328. Few of the edible kinds of fishes are holding their own in their struggle for existence, particularly in those lakes, ponds, and streams where hundreds and even thousands of vacationists fish every year. In some of these localities certain species which used to be abundant are now almost extinct.

FIG. 148.—Part of the fishing fleet in St. John's Harbor. (*Courtesy Dept. of Natural Resources, St. John's, Newfoundland.*)

This fact has been recognized by both the Federal and the state governments, and various organizations have been perfected to remedy the situation. While the United States Bureau of Fisheries and the Fish Commission at Washington have general oversight over the whole matter for the country at large, each state has its own commission of fisheries and game. Millions of young fishes are raised in hatcheries every year and liberated in the lakes and streams to restock them.

329. "Closed seasons" now make illegal the catching of many species of game fishes during the breeding seasons; for to catch one large female fish at this time when it is full of eggs, may decrease the number as much as to catch fifty fishes at other seasons of the year. Likewise, the restrictions as to the number of fishes which may be taken by the fisherman in one day, the

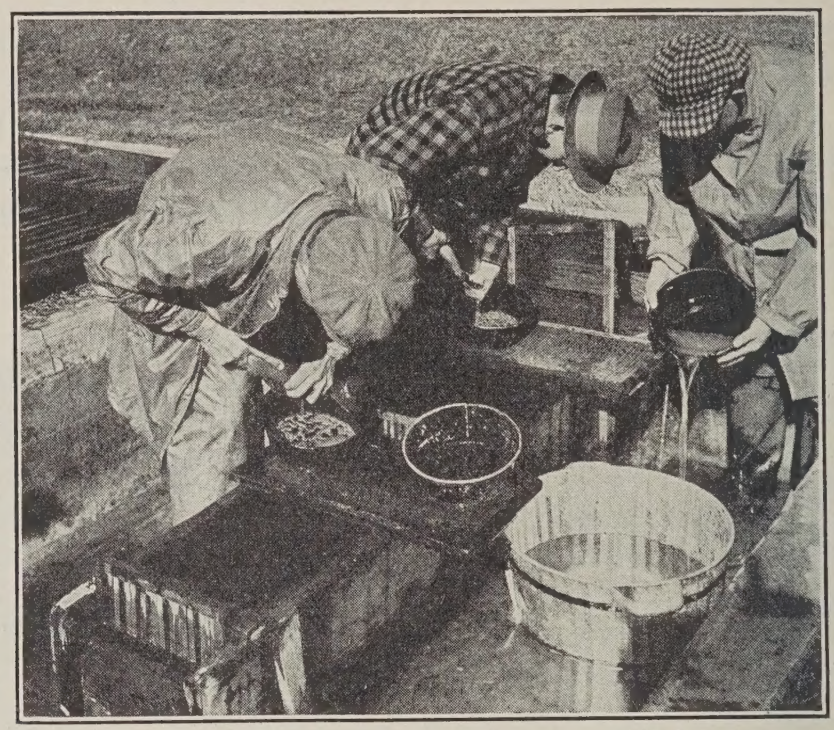


FIG. 149.—"Stripping" the eggs from salmon for the hatchery. A similar process is employed to remove the milt or sperm cells from the male fishes. The two are then mixed to bring about fertilization. (*Courtesy, American Forests, The magazine of the American Forestry Association.*)

FIG. 150.—Equalizing the water temperature in the cans and the brook before liberating young fishes from the hatchery. (*Courtesy Ontario Highway Department.*)

methods of fishing, and the size of fishes which may be taken, all contribute to the preservation of our fish supply for the future as well as for the present.

Interesting Projects

1. From your library read all you can find about the migration of the salmon in the Columbia river. Write out the most interesting facts and give these orally to your class.
2. Watch the fishes in your school aquarium and learn whether the mouth moves when the fish is not feeding. What life function is thus carried on? Notice the movement of the operculum or gill cover. What function is performed by each of the parts of the gill?
3. By watching goldfishes in an aquarium, try to determine for yourself which of the five senses is of the greatest value to the fish in protecting itself against various enemies.
4. Examine a preserved or non-living fish. In which direction do the teeth point? Of what advantage is this unusual position? How many gills has the fish? How does the position of the gill rakers aid in the process of food getting?
5. Take a trip to one of the fish hatcheries in your state. Find out why the fishes of each size are kept apart from the others. What provision is made for a steady supply of fresh water? Are the smallest "fry" given the same kind of food as are the larger fishes?

Review

1. What internal structure buoys up the fish when in the water? Explain how this buoyant effect is obtained.
2. What measures are used to prevent certain species of game fishes from becoming exterminated?
3. What structural adaptations show that the fish is designed for a life in the water?
4. Discuss the need for conserving our food fishes.

Define

artery
auricle
capillary
caudal fin
dorsal aorta
gill arch
gill filament
gill raker
gullet
intestine
lateral line
life history
milt
mucus
olfactory lobes
operculum
pectoral fin
pelvic fin
spawning bed
sperm cells
swim bladder
vein
ventricle
yolk sac

CHAPTER XXI

AMPHIBIANS ARE OFTEN KNOWN AS THE LAND-WATER ANIMALS

330. A little above the fishes, a little below the reptiles, we find these "land-water" animals, the amphibians. Someone has said of them, "They tried to live first in the water and then on

FIG. 151.—The spotted salamander is an amphibian, not a lizard. (*From Surface.*)

land, and couldn't decide on either one." **Amphi** is a Greek word which means **both** or **both kinds of. Bia** likewise, is a Greek word meaning **lives,** so you will agree that **amphi-bia** well describes them. They are not new to you. You have known of toads and frogs for a long time and perhaps have seen the little creatures with the long tails and moist skin, which

probably were described to you as lizards. To many of us these salamanders look just the way we think a lizard **should** look.

A peculiar group they are—as peculiar as some of the things people say about them, such as that toads will make warts on your hands if you handle them—a statement which is, of course, untrue.

331. What, then, is an amphibian? An amphibian is, first of all, a vertebrate with a thin, slimy skin (except in the case of

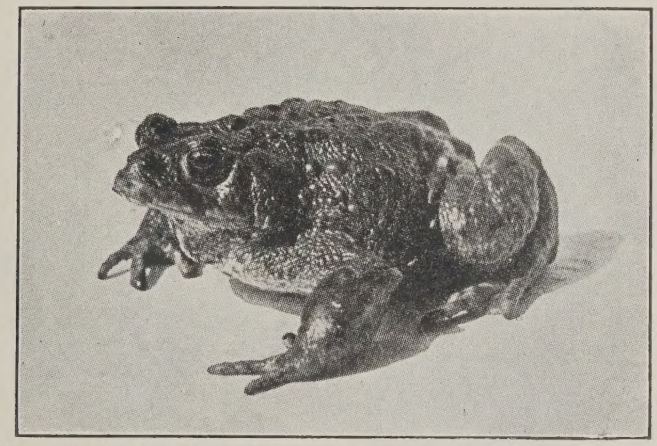


FIG. 152.—Unlike the other amphibians, the toad has a dry skin. (*Holmes.*)

toads) and without any scales or claws. Then, too, it spends its entire life either in or not far from the water. It undergoes a complete metamorphosis—passes through a long series of stages and changes of form and structure during its development. Then there are various other interesting characteristics which enable us at once to identify these animals as amphibians, such as the fact that their larval life (the tadpole stages) is aquatic, like the fishes, while their adult life is terrestrial (lived on land). And still another more wonderful thing about them is that they change their diet and feeding habits when they become adults—giving up for all time the kinds of food they have previously eaten, namely plant and dead animal matter. Other distinguishing characteristics we shall discuss later in this chapter.

332. Frogs.—Probably you are more familiar with frogs than with toads or salamanders, so for our study let us take the frog as our representative amphibian.

333. External Structure.—We are not surprised that the frog is an expert swimmer, for its very structure seems to be designed for this purpose. The body, which is fairly slender and pointed at the head, enables it to glide easily through the water. There are no shoulders which would hold the animal back as it swims, and there are no projecting ears, for the two

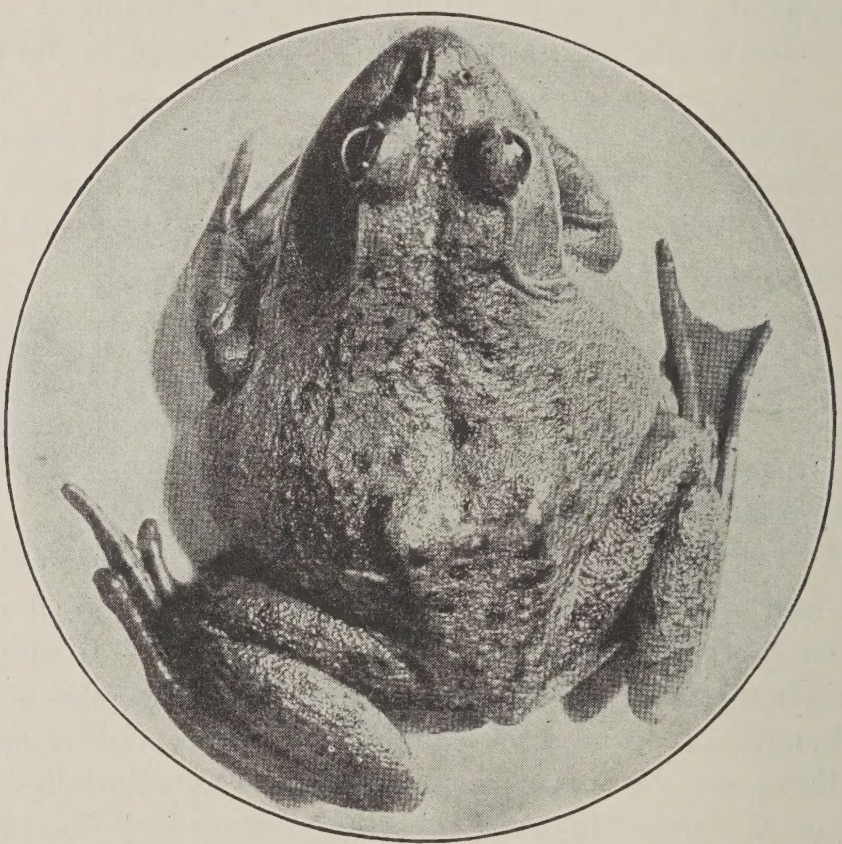


FIG. 153.—The bullfrog requires two years to complete its metamorphosis. (*Holmes.*)

round **tympanic membranes,** or ear drums, lie at the surface of the skin. The hind legs are long and powerful, beautifully webbed for long swimming strokes. The external nostrils, which are located at the tip of the nose, by their very position enable the frog to take in air when its body is nearly submerged in the water. While it is in this position the large periscope-like eyes, projecting as they do above the rest of the head, enable it to see its enemies long before it can be seen by them. The

tympanic membranes catch the sound vibrations from the water as they do from the air when the frog is out on land. Then, too, its skin is so thin and so well supplied with tiny capillaries on the inner surface that the frog can get sufficient oxygen through the skin to supply its needs all winter long while it is hibernating in the mud at the bottom of some pond or stream. Not only does the frog possess all these structural advantages but it is cold-blooded, so that the low temperature of the water during the winter does not injure it. All in all, the frog is a good water animal.

334. But the adult frog is also an equally good land animal. The long, muscular hind legs make it one of our very best long-distance jumpers. It is estimated that the frog is able to jump from eight to ten times its own length. What a record this would be for an athlete! Its enemies find it very hard to grasp, because of the slimy coating of mucus which covers the entire body. Still another adaptation to its needs is its long, sticky, forked tongue with which the frog catches its food. You will find this described later under "food getting." Most species of amphibians possess protective coloration developed to a fine degree. Thus they are quite difficult to see when in their natural surroundings either in the water or on land.

335. Circulation.—The frog, like the toad and the salamander, has a more highly organized heart than the fish. This is one of the reasons for placing it in the next higher class of vertebrates. Here we find a three-chambered heart. There are two auricles and one ventricle. This heart lies in the body cavity about half way between the two arms, and is surrounded by a thin membrane or envelope. Both auricles empty into the one ventricle, a fact which would indicate that both the pure and the impure blood must mix, but by a complicated structure of the valves such mixing is largely prevented.

336. The blood entering through the left auricle passes to the ventricle, thence out by the anterior branch of the main artery and thus carries the purest blood to the head. A second branch of the artery supplies the various organs of the body as well as

the muscles; while the third, or posterior branch, carries the blood which has the least amount of oxygen to the lungs and skin to rid it of carbon dioxide and to take on a new supply of oxygen. The most of the blood in these two last-mentioned branches comes from the right auricle and consequently contains much carbon dioxide gas.

337. An interesting fact about the circulation is that as the blood leaves the various organs it is constantly changing in its composition. For example, that which comes from the stomach and intestines is rich in digested food, while that which has passed through the kidneys has had the nitrogenous wastes removed and really is the purest blood in the whole body. We shall discuss the origin of these wastes under "Excretion".

338. Excretion.—Just as the ashes in the furnace are a waste product of oxidation, so are many of the wastes of the body. Other wastes come from broken-down cells and from general wear and tear of the body. Now all these wastes, among which are carbon dioxide, various salts, uric acid, and water, have to be secreted from the blood stream and excreted from the body. It is the excretory system which does this work. The kidneys remove the uric acid and much of the salts and water; the lungs give off the carbon dioxide and some water vapor; while the skin throws off a considerable amount of water and some salts.

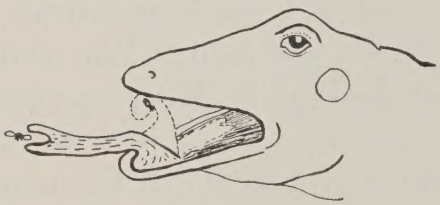


FIG. 154.—Diagram showing use of frog's tongue in catching insects. Notice how the frog's tongue is wrapped around the insect. The frog jumps toward the insect as the tongue is shot out in a motion too rapid to be clearly seen.

339. Food-taking.—Frogs are not at all particular as to what they eat, except that it must be alive and in motion. Insects meet this requirement, and on account of their great numbers, form the main article in the diet of the frog. But other live creatures are also eaten. The writer once pulled a full-grown leopard frog out of the mouth of a bullfrog while it was in the process of being swallowed alive. Frogs have an unusual adaptation for getting their food. If you will examine the

frog's tongue you will notice three things that make it serve admirably for catching insects: it is sticky; it has two projecting tips at the end; and it is attached at the anterior end instead of at the posterior end, as is ours. Have you ever seen a frog catch a fly? It creeps up as near as seems safe; then with a springing leap it shoots forward, and throwing the tongue clear out it pulls the insect back into the mouth and rapidly swallows it. All this is done so quickly that one cannot even see the tongue. There is only a flash. Rarely does the frog miss its prey.

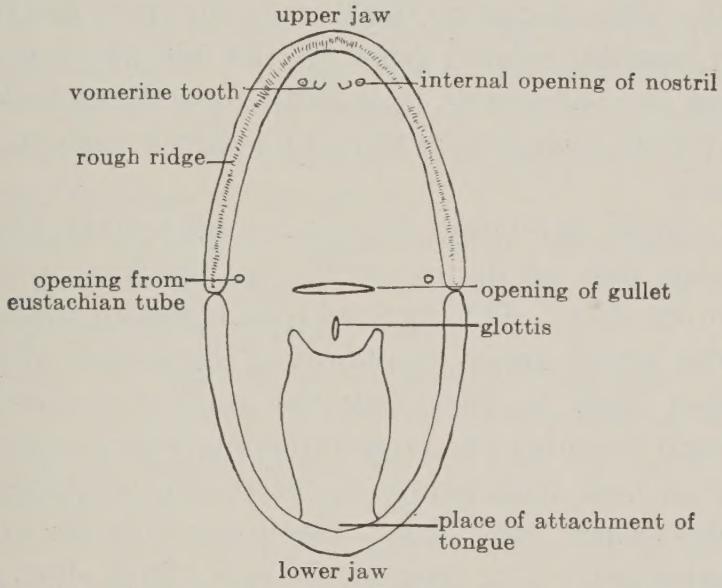


FIG. 155.—Structures seen in the wide-open mouth of a frog.

340. Digestion.—The alimentary canal, or food tube, starts at the mouth. Here we find no teeth of the usual kind but two vomerine teeth which have flat tops. These are located in the middle of the roof of the mouth near the internal openings of the nostrils. The bony ridge on the upper jaw also serves to prevent the larger prey from escaping.

341. From the mouth the food is pushed backward through the throat or pharynx into the gullet, which in turn conducts the food to the stomach. This organ, like the esophagus, is quite distensible, so that surprisingly large bits of food can be swallowed. At the posterior end of the stomach we find the small intestine, which is the most important part of the whole food

tube. Here the greatest part of the work of digestion and absorption is carried on. The grayish white digestive gland, the pancreas, can be seen lying in the bend of the stomach, between it and the beginning of the small intestine.

342. The largest gland in the body is the liver, which is dark red in the living frog and grayish brown in preserved specimens. This digestive gland is broad and flat, and has three lobes extending clear across the body cavity. In the ordinary dissection we find it just ventral to the stomach, covering up the anterior portion of it. Just dorsal to the liver is the little green sac, the gall bladder, usually colored green by the bile which it contains. The bile and the pancreatic juice both pass through ducts into the small intestine near its anterior end, aiding greatly in digesting the food mass.

343. The small intestine shortens considerably during the metamorphosis due, no doubt, to the change from a vegetarian to a carnivorous diet. The digested food is readily absorbed into the capillaries which are so abundant in the tissues of the intestine. Further back in the body the small intestine becomes abruptly larger, forming the large intestine, which is about three quarters of an inch long before it enters the common sewer of the body, the **cloaca** (*klo-ā′-kah*), which opens to the exterior.

344. Respiration.—The frog at various times during its life history, has four methods of breathing. When first hatched, the tadpole, as the larval stage is called, breathes by external gills—little fringe-like structures which project outward from each side of the throat. In a few days these are replaced by internal gills and the tadpole then breathes like a fish, taking in the water through its mouth. Later, after lungs appear, and for the rest of its life except during the winters, it breathes air. The air enters the nostrils, passes backward through the mouth cavity, the glottis, the laryngo-tracheal (*lar-in-go-trā′-ke-al*) chamber (where the vocal cords lie), and into the lungs. The lungs are spongy, elastic sacs, which have a central canal, and are well supplied with minute blood vessels to receive the oxygen as it leaves the air and enters the blood stream.

345. With no diaphragm and, consequently, no thoracic cavity to aid in breathing, how do you suppose the frog forces air into its lungs? The process is a unique one.

Inspiration, or the filling of the lungs with fresh air, consists of two steps:

(*a*) First the floor of the mouth is lowered, and the mouth cavity is thus made larger. The air within becomes thinner or less dense than the outside air. Since the nostrils are open, the outer air rushes in and fills the mouth cavity.

(*b*) Next the nostrils close, imprisoning this mouthful of fresh air, and the floor of the mouth rises, compressing the air. As the pressure of this air becomes greater, it naturally seeks to escape, but the only exit being downward into the lungs, it escapes that way, filling the lungs with fresh air.

After remaining in the lungs a moment, this air becomes stale by losing much of its oxygen and receiving carbon dioxide gas, and must therefore be exhaled from the body.

Expiration, like inspiration, consists of two steps:

346. (*a*) First the mouth floor lowers, releasing the pressure that we mentioned just above, the air being no longer held in the lungs under pressure, as it was. More than that, the lungs of the frog are elastic sacs, which like a toy balloon, collapse at the first opportunity. Here is the chance for escape, and the stale air at once passes into the mouth again.

(*b*) The nostrils are now open and once more the mouth floor rises. The stale air is slightly compressed, but only very slightly, for it takes the path of least resistance and escapes through the open nostrils to the outside. The two movements of inspiration and the two of expiration have been completed, and this cycle of movements is repeated again and again.

347. Frogs spend the winter in a sleeping stage known as **hibernation** in the mud at the bottom of ponds and streams. The nostrils then remain closed. The thin, moist skin is well supplied with capillaries (which you can easily see in a dissected specimen). These capillaries receive their oxygen supply from

the oxygen dissolved in the water, which passes directly from the water into the blood stream.

348. Nervous System.—The brain of the frog is more highly organized than that of the fish. We can easily distinguish the rather large **cerebrum** (*ser'-e-brum*), the area of the brain which controls memory. This tapers off into the smaller **olfactory lobes**

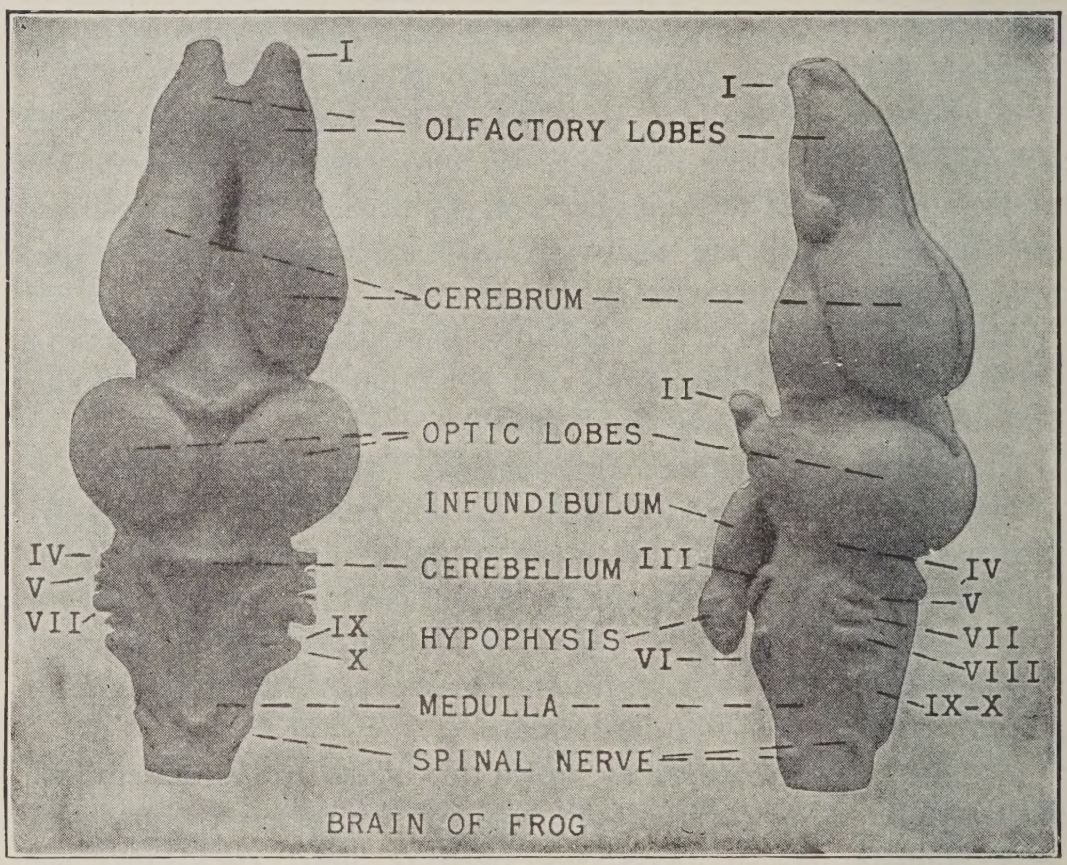
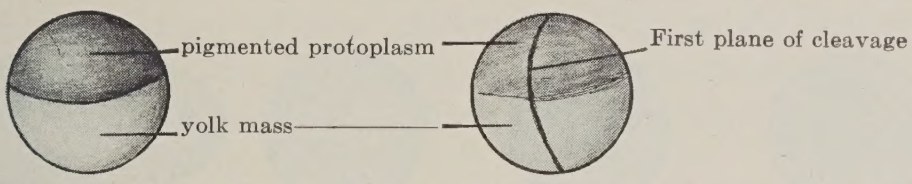


FIG. 156.—Dorsal and side views of the brain of the frog. The cranial nerves are numbered from I to IX. (*Atwood.*)

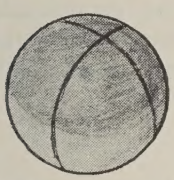
directly in front of it. These are the brain centers of smell. Just posterior to the cerebrum we see the two large **optic** lobes (the areas of sight), from which a nerve runs to each eye. Then immediately behind the optic lobes is the narrow **cerebellum** (*ser-e-bel'-um*) lying crosswise. Its function is to coördinate the muscular movements so that they can work together. The **medulla** (*me-dul'-ah*), lying immediately behind the cerebellum,

is the hindermost part of the brain and regulates the heart-beat and also respiration. In shape it is somewhat triangular, tapering off at the posterior end into the spinal cord, which continues down through the neural canal of the vertebrae, the entire length of the trunk. Ten pairs of nerves, known as **spinal nerves,** run outward from it, supplying the various parts of the body.

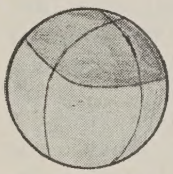


The fertilized egg is the first stage of the embryo.

The cleavage plane divides the first cell into two cells of equal size.



The second cleavage plane forms at right angles to the first one. Now there are four cells of equal size.



The third cleavage plane forms at right angles to the first two planes. The yolk or food material is heavier and it settles in the lower cells making them larger.

FIG. 157.

349. Life History.—In the early spring the frogs lay their eggs, grouped together in the shallow water of the swamps and at the edges of streams. They resemble a grayish white mass of gelatine the size of a man's fist. Each egg is dark on one side (the protoplasm), shading off into a light color (the yolk mass) on the other side. Each egg is spherical in shape, about the size of the "lead" in a pencil, but, being covered with a gelatinous coating for protection, is altogether about half an inch in diameter. Frogs

differ from most animals in that the eggs are fertilized while they are being laid. After a few days of warm weather the eggs develop into tadpoles. But in the meantime some very interesting changes have been taking place. What has gone on within the egg while it has been developing into a tadpole?

350. Cleavage Stages.—Among all animals the fertilized egg consists of but a single cell, and the frog is no exception. If we

The early blastula, cut across the center to show its cavity. The lower cells are larger because they contain more yolk.

The later blastula. No new material has been added, but the central cells migrate to the outside, forming a cavity. Therefore this stage is larger than the fertilized egg. Because of repeated cell divisions the individual cells have become very small.

The yolk gathers in the cup which is formed when one side of the blastula caves in, to form the gastrula. This cupful of yolk is sometimes called the *yolk plug*.

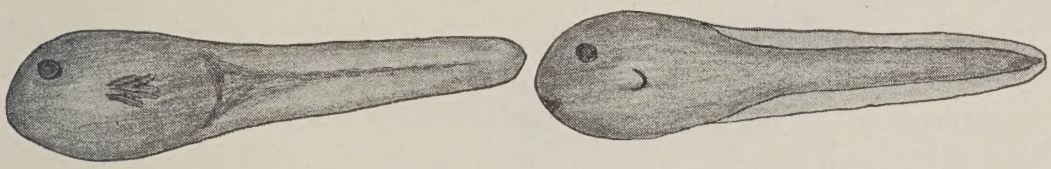
The gastrula lengthens and the organs of the tadpole begin to form. The groove along the top is known as the *neural groove*.

FIG. 158.

had the patience to watch that egg through a lens for several hours we should see a faint line coming across it and cutting it in halves. The two halves do not separate but remain close together, as you can see in the accompanying diagram. Then another "plane of cleavage," as it is called, can be seen, at right angles to the first one. Our embryo now consists of four cells. The next cleavage or division is at right angles to the previous ones, cutting the cells into upper and lower halves. This process can best be understood by referring to the accompanying diagram. It continues until a large number of cells have been formed into a structure which is known as a **morula** (*mor'-oo-lah*).

351. By the movement of the internal cells to the surface, this solid ball of cells then becomes slightly larger. It also becomes hollow, like a hollow rubber ball. It is now known as a **blastula.** Then one side of this hollow ball caves in, forming a double-walled cup, the **gastrula.** The edges keep on folding over until they meet and grow together, thus forming the beginning of the body cavity.

The outer layer of this gastrula, known as the ectoderm, eventually gives rise to the skin and the nervous system. The middle layer, the mesoderm, likewise forms the muscular, the



In the first tadpole stage, the gills are external. The mouth has not yet developed.

In the second tadpole stage the gills are internal and there is one opening to permit the outward flow of the water which has entered through the mouth. The opening and its cover, or *operculum*, are on the left side.

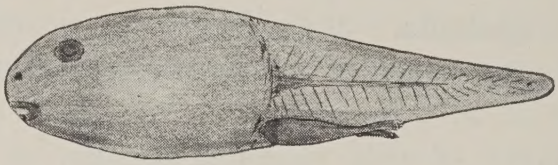
FIG. 159.

skeletal, and the circulatory systems; while the inner layer, the endoderm, produces the digestive and respiratory systems. All of the vertebrates and many of the invertebrates pass through these same stages.

352. Metamorphosis.—When first hatched, the tadpole is a curious little creature with a fairly long tail and no mouth. At your first opportunity you should examine one under a lens and find out why it does not need a mouth.

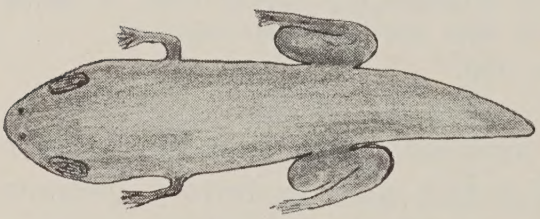
The most striking thing you will notice is the fringe of external gills which resemble tiny fingers along each side of the throat. It is through these external gills that the tadpole breathes during the first few days, while its mouth, internal gills, and other organs are being formed. Later the tadpole breathes through the mouth like a fish, taking in its oxygen from the water. The external gills have now been absorbed—but where are the gill

slits? On the right side they are entirely closed over by skin. On the left they appear only as a roundish exit tube leading from the chamber within, where the gills are found.

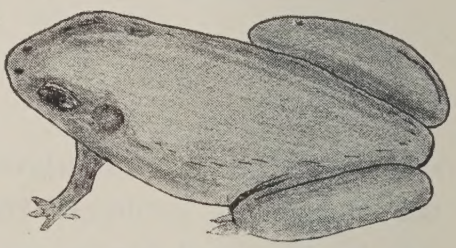


The hind pair of legs develops first. Lungs are developing and the tadpole uses them part of the time.

The front pair of legs develops next, but the tail continues to be the chief organ of locomotion.



As the legs develop the tail is absorbed. Now the tadpole is able to move about successfully on land.



The adult frog lives equally well on the shore or in the water. Breathing by lungs when at the surface or out of the water, and by means of its skin, which has many blood vessels, when under the surface of the water, the frog well illustrates its class name, *amphibia*.

FIG. 160.

353. Now that the tadpole has a mouth and its yolk supply is used up, it swims about, feeding on the algae that grow in the water. Many internal changes have been taking place all the while. Soon the hind legs begin to form. The tadpole grows; the front legs and the nostrils appear; lungs have formed, and the

tail is gradually absorbed. The internal gills disappear and the little creature that *was* a tadpole now crawls out onto the land where it goes in search of insects and other animal food. It breathes air and is no longer a tadpole, but a frog.

354. Economic Importance.—The economic importance of the amphibians is threefold; they serve as insect destroyers, as food for man (in the case of the frog), and for laboratory purposes. If you have ever watched a frog or a toad in some quiet, sunny spot snapping up flies, you were probably surprised at the large number it could catch within a few minutes. It is now known that every frog and toad kills thousands of insects—many of them injurious—every year. Frogs' legs are sought as a table delicacy by the more exclusive hotels, and hundreds of thousands of frogs are caught annually and sold as dissection material for biological purposes. In fact, they have been caught in such large numbers that certain states have established "closed seasons" so that they may not be exterminated. It is obvious that amphibians should never be killed needlessly.

Interesting Projects

1. In early spring visit some swamp or marsh and look for frogs' eggs floating in the shallow water near the shore. If found, collect a few in a dish half full of the swamp water. Keep at about the same temperature, if possible, and watch the young tadpoles develop from the time they hatch. Change the water every day at first, then oftener as the tadpoles become more active.
2. Watch any toads or frogs which you can find. What food do they eat? Why is it impossible to see the food being taken into the mouth? Do they feed mostly on dead or on living prey? Do they locate their prey by its shape and color or by its movement?
3. Using a preserved specimen of a frog, cut the sides of the mouth so that it can be opened wide. Lift up the tongue. At which end is it attached in the mouth? How does this attachment enable the frog more successfully to catch moving insects? Notice the rough ridge around the upper jaw. Where are the two flat-topped vomerine teeth located? How are these teeth probably used? Make a drawing of the wide-open mouth of the frog. Label all structures seen.
4. Using scissors and forceps, carefully remove the skin and the muscles from the entire ventral surface of the trunk of a preserved frog. Examine

each of the organs which make up the digestive system. In an outline of the frog carefully draw each of the organs of the digestive system, and with the aid of your textbook label each part seen.

5. Describe the location and the function of the (*a*) heart, (*b*) lungs, (*c*) kidneys, and (*d*) spinal nerves.
6. When on a field trip, collect a few newts or small salamanders. These small amphibia will make interesting additions to your school aquarium.

Review

1. What does the word "amphibian" mean?
2. In what ways are these animals more highly developed than fishes?
3. Where do frogs hibernate during the winter?
4. What very unusual change of diet is seen during the metamorphosis of the frog?

Define

adaptation
anterior
bile
cerebellum
cerebrum
cold-blooded animal
diaphragm
expiration
gall bladder
glottis
hibernation
inspiration
laryngo-tracheal chamber
liver
lungs
medulla
morula
nostril
oesophagus
olfactory lobes
optic lobes
pancreas
pancreatic juice
pharynx
plane of cleavage
posterior
salamander
spinal nerves
tadpole
thoracic cavity
tympanic membrane
ventral
vocal cords
vomerine teeth

CHAPTER XXII

MODERN REPTILES ARE THE LAST SURVIVORS OF A MIGHTY RACE

355. The Ancient Reptiles.—A mighty race, lords of the earth, were those old reptiles of the far distant past. Some of them continued to grow until they were among the largest animals that have ever lived on the earth. To see their skeletons in the

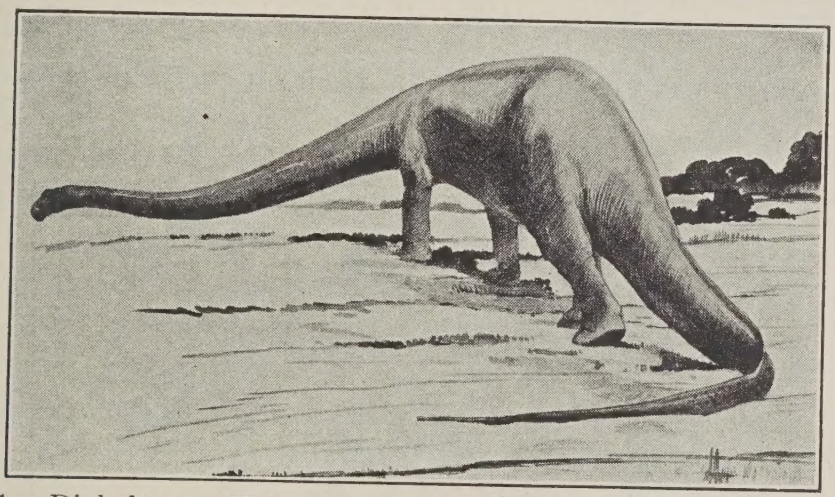


FIG. 161.—Diplodocus. This was one of the giants that roamed the earth millions of years ago. (*The American Museum of Natural History.*)

museums and to read about them in the scientific textbooks is like going back in your ancient history to see what was written before page one. Or, it is as if you could look through some magic window into the dim past, and there see those great lizard-like creatures roaming over the earth, fighting their enemies, waging war on each other, and living their lives as animals do today.

I am sure you will want to look up "Dinosaurs" (*di'-no-sors*) in your school library or the public library and there read about the lives that these creatures lived back in prehistoric times before

man came into existence. Then you will be curious and will want to see what they look like. A trip to any of the large natural history museums will give you several hours of very

FIG. 162.—Tyrannosaurus (left) and Triceratops (right) were two of the giant reptiles that were living on the earth long before the appearance of the human race. (*The American Museum of Natural History.*)

real enjoyment as you examine the peculiar forms of those giants of the long ago.

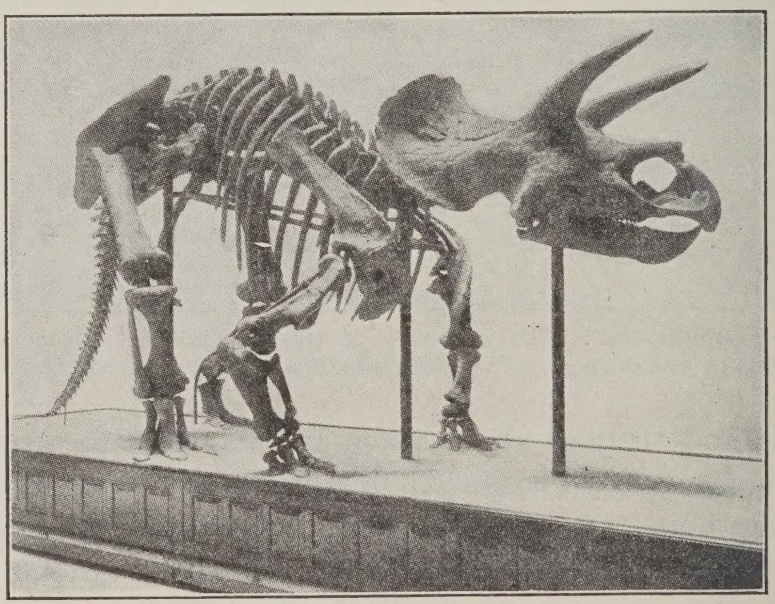


FIG. 163.—A dinosaur, *Triceratops.* (*After Gilmore.*)

356. The Reptiles of Today.—All of those large reptiles are now extinct, but the race of reptiles is represented by four groups or orders, as we find them today. These groups are as follows:

1. Snakes
2. Lizards
3. Turtles
4. Alligators and Crocodiles

357. But before we begin really to study the class of reptiles, let us ask of ourselves, "What is a reptile?"

A reptile is a vertebrate which (1) has a dry, hard skin, covered with matched scales; (2) has two auricles and a partly-divided ventricle (except in the case of alligators and crocodiles); (3) has no metamorphosis; (4) breathes by lungs throughout life; (5) and has eggs covered with a rubbery or leathery shell, in most cases. (A few species have hard shells).

358. Snakes.—What has probably impressed you as the most striking peculiarity about snakes is that they have no legs. They have long, round bodies, a fairly small head, and an exceedingly large mouth. If you have ever seen the open mouth of a snake, you have noticed that it extends much farther back than the eyes. Notice this fact in Figure 167. Have you ever seen a snake that has just swallowed an egg, a frog, or a mouse? Could you watch the "bunch" or swelling move along as it passed on to the stomach? Possibly you wondered how it could swallow such a large object. The mechanism for doing this is deserving of notice. Many of the reptiles have the unusual power to disarticulate (*dis ar tik'u lāt*) their jaws; that is, they can unfasten them and allow the lower jaw to drop down. Thus they can swallow food which is larger than the head of the snake itself. Reptiles do not chew their food; they simply swallow it.

359. Most snakes reproduce by means of eggs which are fertilized before being laid. These are generally placed in a sandbank or in some similar place and left there, covered over with sand, to hatch by the heat of the sun. A few species of snakes bring forth their young alive. The writer once had a large garter snake which gave birth to forty-three tiny young. These were amusing little creatures, about an inch and a half long. They were very fond of small pieces of earth worms. Sometimes two of them would take hold of the two ends of a piece of worm and eat until

their heads came together. Then one of them was compelled to let go. Water snakes, copperheads, and rattlers are among other species of viviparous snakes (those that bring forth their young alive).

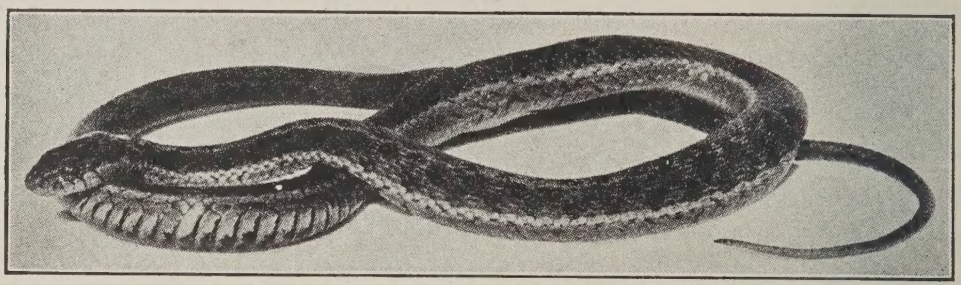


FIG. 164.—Garter snakes destroy large numbers of injurious insects. (*Holmes.*)

360. Poisonous Snakes.—Many a person has been deprived of an interest in reptiles because someone in the past has aroused in him a fear of them. This fear is always unfortunate. We should learn to identify the common varieties of snakes, especially the copperhead, the rattlesnake, and the water moccasin, or "cotton-mouth" snake. These are the three really dangerous species in

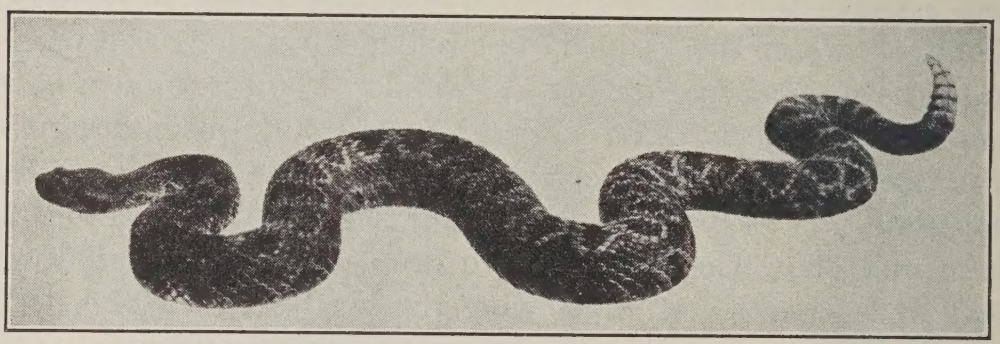


FIG. 165.—The rattles of the rattlesnake are formed from the remnants of its shedding skin. (*Zoölogical Garden of Phila.*)

the United States, besides the coral snakes and the pigmy rattlers of the southern states. The other local species are harmless, although some of them, such as the black snake, will frequently "strike."

361. When a person is "struck" by any of the harmless species such as a black snake, he is simply bitten and there is no more danger than if bitten by a cat. Whenever a person is bitten by

a snake—or by any other animal, for that matter—a few drops of some disinfectant, such as iodine, should be put on the broken skin, to destroy any germs which may have entered at the time. It is wise always to play safe about possible infections from any source whatever.

The habit so frequently noticed among snakes, that of darting the forked tongue outward and back, has nothing whatever to do with striking. The tongue serves as a delicate and sensitive organ of touch to aid the somewhat poor eyesight.

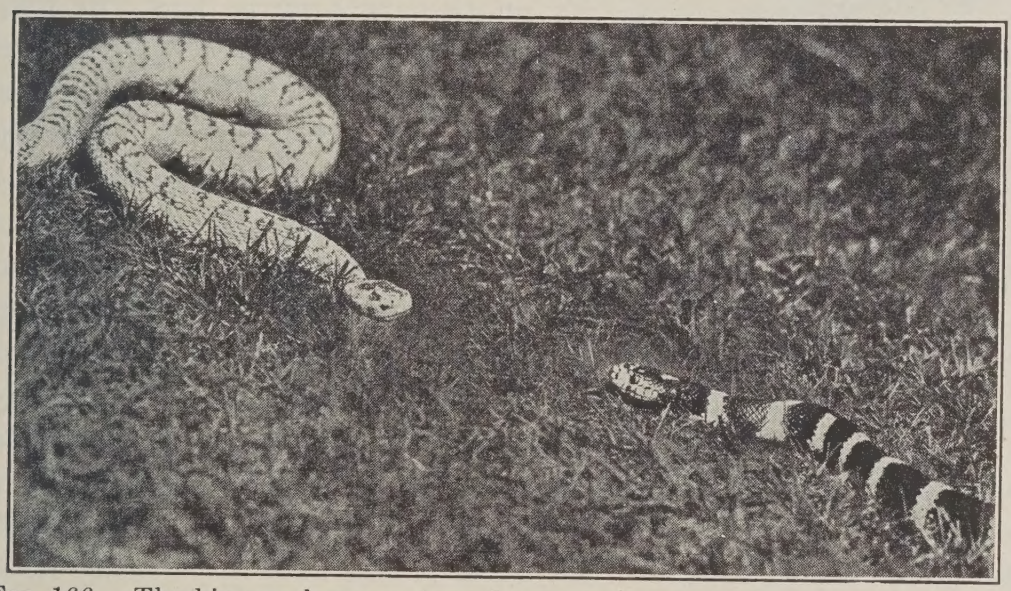


FIG. 166.—The king snake cannot produce a venomous poison, but it can kill a rattlesnake. (*Corwin and Corwin.*)

362. We should understand just why a rattlesnake is dangerous and a black snake is not. All snakes have teeth but only those having **fangs** are poisonous. A fang is a modified tooth, longer than the others, and is hollow, having at its base a poison gland. When any poisonous snake, such as one of the three species mentioned above, strikes, the muscles press on this gland, thus forcing the poison into the fangs; these, like a hypodermic syringe, force the poison into the victim. Reports show very few deaths from poisonous snakes in the United States, usually not more than two or three a year. On the other hand, the number of such deaths in India is very large. The official

figures show that in that country, 22,000 deaths every year are caused by the bites of the cobra and other poisonous snakes. To a great extent the large number of deaths is due to the cobra's being considered sacred, and also to a general indifference on the part of the people about going bare-legged through the jungles which are known to be infested with several species of poisonous snakes.

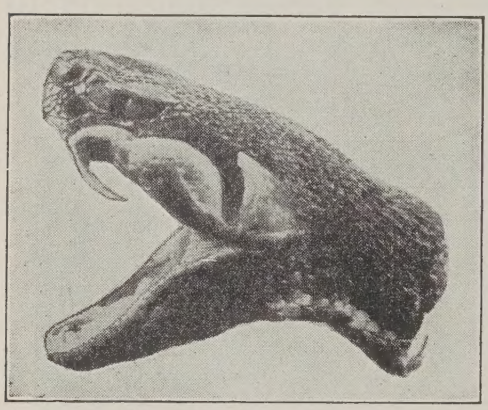


FIG. 167.—Head of rattlesnake, dissected to show the oval poison gland behind and below the eye. A duct leads from the gland to the hollow fangs. (*Reese.*)

363. Treatment of Snake Bites. Since these bites are nearly always on the arms or the legs, the first precaution is to keep the venom from spreading to other parts of the body. This may be done by quickly putting on a tourniquet (*toor'-ne-qet*) (See Fig. 314), thus shutting off the flow of blood from the bitten area. Then a sharp knife or razor blade should be used to enlarge the punctures made by the fangs, so that as much of the poison-laden blood as possible may be drained off. To do this requires courage, but it is absolutely necessary. The blood should be made to flow from these lacerations by sucking it, if necessary. Although for some time a solution of potassium permanganate was thought to be beneficial for use on snake bites, recent authorities do not recommend its use.

A good surgeon is needed at once if it is possible to obtain one. He will probably inject anti-venin serum, the only really effective remedy, as soon as it can be obtained.

364. Popular Errors about Snakes.—There are many common notions about snakes which, although unfounded, are generally believed. One of these is in regard to the "hoop" snakes. Some persons claim that these snakes take the form of a hoop and can roll away very rapidly. Of course this is untrue. Another error is that milk snakes do a considerable amount of harm in pastures by drawing milk from the cows. As a matter

of fact, milk snakes do not care for milk when it is offered to them. Another more or less general belief is that one can tell the age of a rattler by counting the number of its rattles. The truth is that rattlesnakes form two or three of these knobs every year, and there are records where even four have been formed in a single year. Some persons believe the forked tongue, often seen darting back and forth from the mouth, to be fangs. All these popular notions have no scientific foundation.

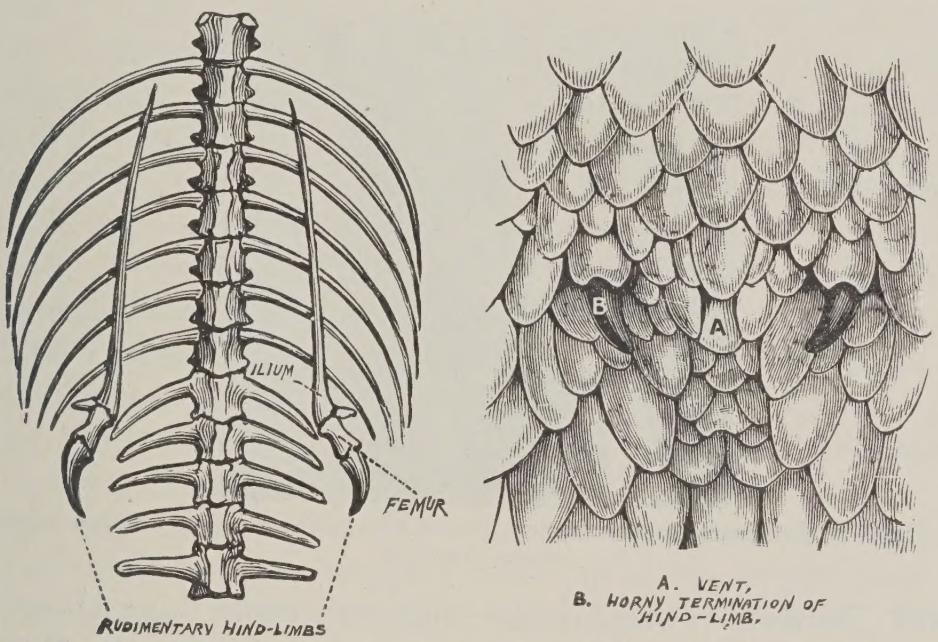


FIG. 168.—The skeleton of the python shows that certain snakes apparently developed from a kind of reptile that had usable appendages. (*After Romanes.*)

365. Before we leave our study of snakes, we might ask this question, "Is the absence of legs as great a handicap as is generally believed?" If the snakes of today possessed legs, they would doubtless be as short as are the legs of other animals of equal size (diameter of body). It seems doubtful whether such short legs would increase the speed which snakes now possess when escaping from their enemies. Also, such short appendages would probably hinder rather than aid them when crawling out of sight, a thing which they now do rather speedily. Therefore would not the presence of short legs be a handicap to them, rather than a benefit?

366. The rapid movement of snakes is partly due to the presence of the flat, horny plates, called **scutes** (*skūtz*), which lie along the entire ventral surface of the body. These are not scales, although derived from them. When these scutes are slightly tipped, a more gripping surface is produced, which aids the snake in getting a "footing". The method of crawling, which is observed best when a snake is placed on a smooth surface, is one of the interesting ways of this group of animals.

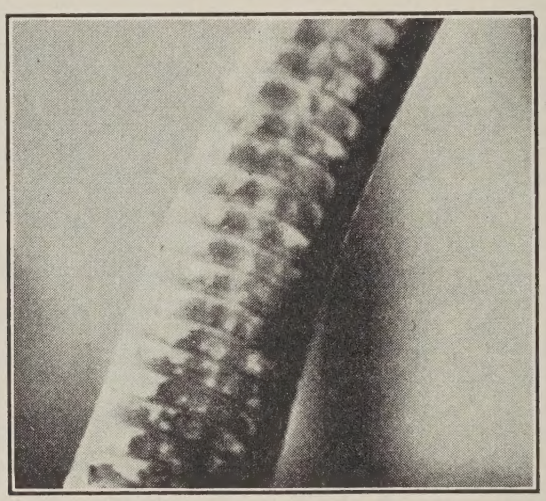


FIG. 169.—The scutes on the under side of the snake enable it to get a footing when crawling.

367. Turtles.—Probably the most noticeable thing about the turtles is their shell—and what a protection they have! But the most **characteristic** thing about them is that they have two skeletons. The outer shell, really an exo-skeleton, is made up of bony plates covered by horny scales. These are derived from the skin and not from the true skeleton. The upper part of the shell is known as the **carapace** (*kar'-ap-ace*) while the lower part is the **plastron** (*plas'tron*). This exo-skeleton is very strong and offers a variety of shapes, sizes, and color patterns in the different species. As to size, turtles vary from the large leatherback marine turtles, whose long flippers stretch nine feet from tip to tip and which often weigh 1000 pounds, down to our common mud turtle, whose carapace is not usually more than $3\frac{3}{4}$ inches long.

368. We generally think of the shape of a turtle as being oval, but we should remember that some species, such as the leather-back or trunk turtle have a carapace five feet long and perhaps four feet wide. This width being at the shoulders and the long shell being furrowed lengthwise, the turtle appears kite-shaped, especially when the flippers are folded back, as they often are.

369. Again, we think of turtles as being dark gray or brownish. Do you know the painted turtle? It is one of our common species. The carapace varies from dark olive to black, bordered with crimson and black both above and beneath. The plastron is pale yellow. It never grows large, being rarely over five inches, and is an addition to any terrarium (*ter-rar'-e-um*)[1] which offers a pool of water as well as the soil. This little animal is fond of raw chopped meat, earthworms, the larvae of insects, and water plants. If placed in an aquarium, it is likely to catch and eat the small fishes which chance to come near it.

370. There is also the diamond-back terrapin, found in the salt marshes of the Atlantic coast and the area further south along the borders of the gulf states. Its olive-gray carapace is curiously patterned with dark rings which give it its name. The larger individuals of this species are becoming rare and are rather valuable, often bringing from five to ten dollars each.

The spotted turtle, common from Maine to Indiana, is also well worth knowing. Its black shell is marked by a great many round yellow spots. This is an aquatic species which, like the painted turtle, seems to swallow more easily if its head is beneath the surface of the water. In captivity it feeds on chopped raw fish. It will also nibble on lettuce leaves.

The box turtle is very well named and has the best protection, as it can draw its head and legs entirely within the shell and close itself up so tightly that no enemy can pull it open.

[1] A terrarium may easily be made by covering the bottom of an aquarium tank with different kinds of soil, rocks, moss, and sand. A wide variety of plants as well as small animal life may be raised here after being brought in from field trips. (See Fig. 170.)

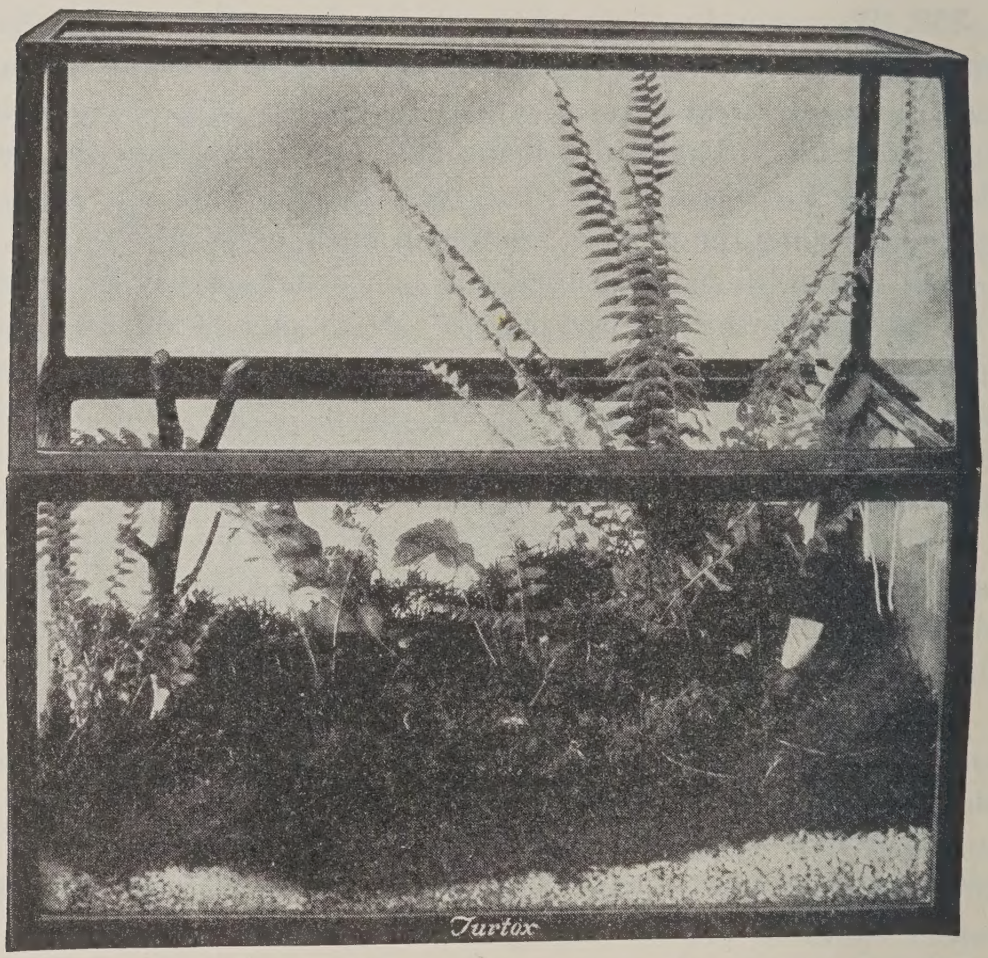


FIG. 170.—A terrarium is a constant source of interest in the classroom. (*Copyright by General Biological Supply House, Chicago.*)

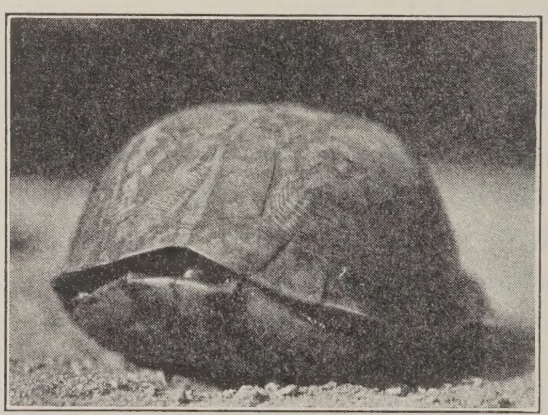


FIG. 171.—"Not at home, thank you." Box turtle entirely within shell. (*Courtesy, American Forests, the magazine of The American Forestry Association.*

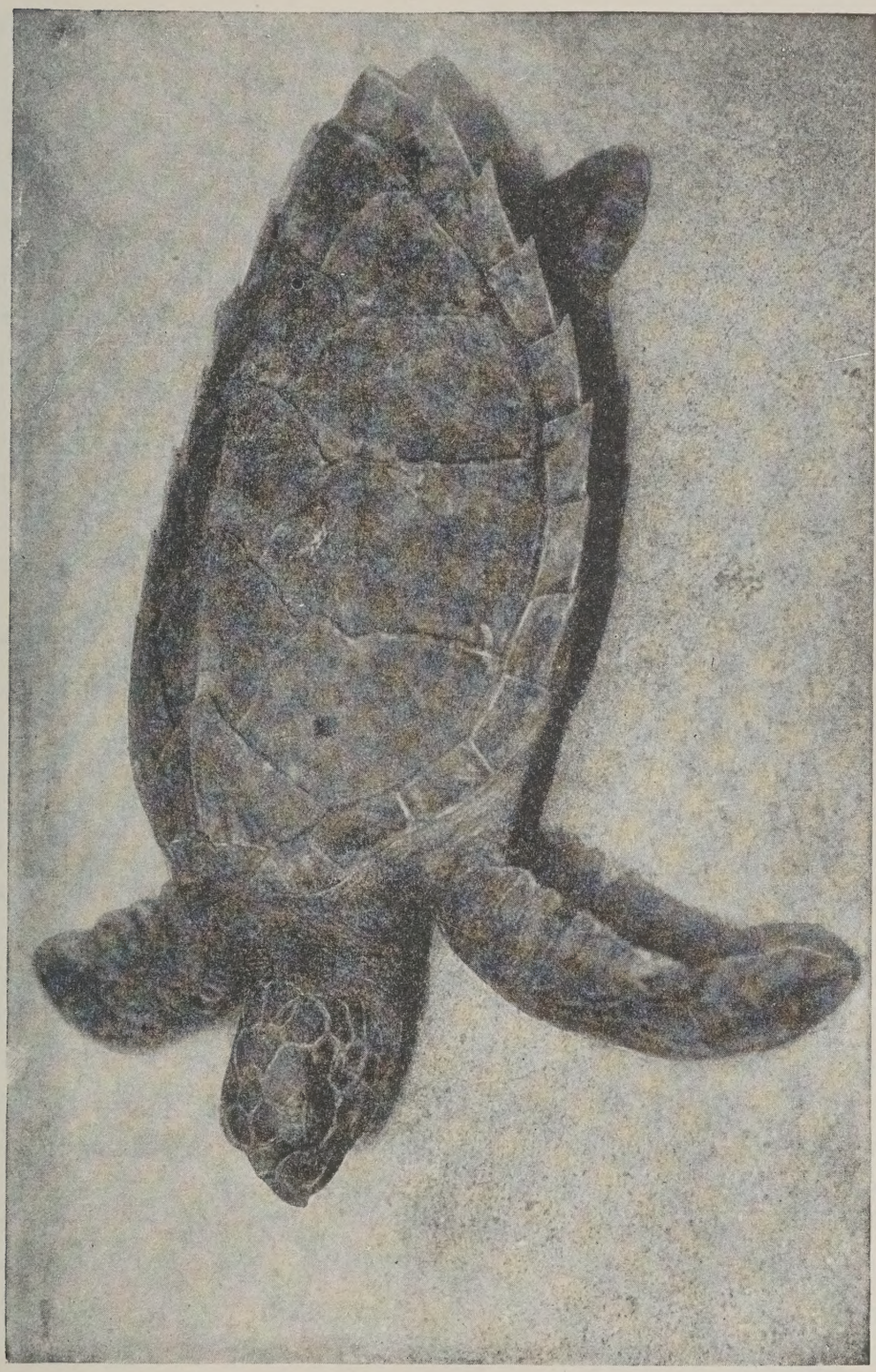


FIG. 172.—The Hawk's bill turtle supplies the valuable "tortoise shell." This marine turtle may be identified by its overlapping plates. (*From Ditmars' "Reptile Book."*)

371. All turtles breathe by lungs and undergo no metamorphosis. Some of them live to be very old. One often hears of persons who come across a turtle which bears marks cut in the shell many years before, although these marks give no authentic record of the true age of the turtle.

372. The economic importance of turtles is largely due to, (1) the use of "tortoise shell" for the rims of eyeglasses, combs, and the backs of small mirrors; (2) the use of the flesh of some species as food; (3) and the damage which snapping turtles cause by destroying large numbers of valuable game fishes as well as the eggs and young of many water and game birds.

"Tortoise shell" comes only from the hawk's bill turtle, one of the sea turtles easily distinguished by the overlapping **plates** of its carapace. The flesh of the green turtle and of several species of terrapins, especially the diamond back terrapin, is eagerly sought as a delicacy. When eight inches long these terrapins are sold to the markets for as much as $50 a dozen.

373. Snapping turtles, especially, destroy a large amount of valuable wild game. In speaking of the damage caused by these turtles, Dr. Raymond L. Ditmars, an authority on reptiles, says of the snapping turtle "As in their native state these turtles lie partially embedded in the mud of the river-bottom, the rapid movements of the head and neck are important in the capture of fish, which form the larger portion of the food. But the snapping turtle is an exceedingly voracious brute, and is not particular as to its fare. Young water fowl are stalked from beneath the surface, seized by a dart of the jaws, and pulled below to drown and be quickly torn to pieces by the keen mandibles assisted by the front limbs. The turtle is entirely carnivorous."[1] During one summer recently, in the Shade Swamp sanctuary in Farmington, Conn. where these turtles killed hundreds of otherwise protected animal life, more than three thousand pounds of snapping turtles were caught in traps especially designed for them and placed in the swamps there. Similar

[1] *The Reptile Book*, pp. 13–14, Doubleday, Doran & Co.

FIG. 173.—Snapping turtles destroy many fishes and the young of water birds. (*From Ditmars' "Reptile Book."*)

efforts to reduce their numbers have been made in other parts of the country.

374. Turtles lay their eggs in sand banks or in the soil along the shores, cover them over, and go away and leave them, giving them no parental care whatever. The heat of the sun hatches the eggs, and the little turtles come crawling out, looking for something to eat.

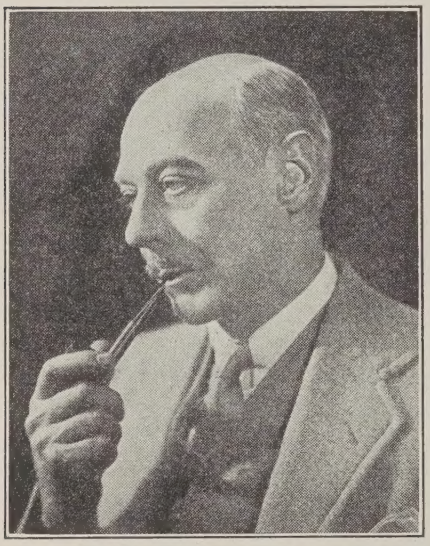


FIG. 174.—Raymond Ditmars (1876–), for many years curator of reptiles at the New York Zoological Park is the author of our best books on reptiles.

If you would see some really large turtles, you should see the large marine turtles, such as those kept alive at the Aquarium in New York and in other large cities.

375. Lizards.—Few lizards are found under natural conditions in the northern part of the Eastern United States. In the west, some species are found as far north as the state of Washington. Many times some friend of ours has told us about some "lizard" which he has found down cellar, or maybe under a stone out in the garden. Perhaps he even told us about the slimy skin. We know that it was not a lizard at all, but one of the salamanders which are fairly abundant in places of this kind. Of course the lizards have scales, like all true reptiles, and their skin is always dry.

376. Several species of lizards are found in the southern half of the United States as well as in nearly all of the arid areas and tropical parts of the other countries. Lizards, for the most part, are agile, heat-loving animals of varied colors. One of the brightly colored forms is the collared lizard which is quite abundant from Missouri to Eastern California. Its body varies in color all the way from a yellowish or light gray, to green. Numerous red, white, and yellow dots serve further to decorate it. The neck is conspicuously marked by two wide black bands. But most of the lizards are brownish or gray.

377. Perhaps when we were children we saw at the circus some of those curious little creatures with the long tails, that a man was selling as he took them from a board. Sometimes they looked green and at other times brown. These were chameleons (*kam-e'-le-unz*), which had been brought up north from the southern states, or perhaps from Cuba. They have the remarkable ability to change the color of their skin by changing the size of the chromatophores (*kro'-mat-o-fōrz*) (color patches). This change is partly a chemical reaction and partly a nervous reflex. It is a popular idea that this lizard changes its color in order to secure protection by taking on the color of its environment, but this is untrue. The change of color is due to the conditions of light and temperature as well as to fear and anger. While asleep these lizards are always light green. At other times, they may be light or dark brown and even gray with spots.

378. Among the various groups of lizards we find some very unusual habits as well as unusual structural forms. The glass "snake," as it is commonly called, is a lizard that has a habit of escaping from its enemies by shedding its tail if it is caught and held by that organ. It regenerates or grows a new one without the least difficulty. The Mexican horned lizard, 5¼ inches long, when angry or excited, has been seen to throw from its eyelids a very tiny stream of blood, as fine as a horse hair, for a distance of four feet. Dr. Ditmars tells of one instance in which he noticed 103 of these blood spots each about one eighth of an inch in diameter. The gila (*hé-lah*) monster, 19 inches in length, and very poisonous, is found in southern Arizona and New Mexico. Despite its sluggish appearance, it is very quick, and snaps at any enemy with great speed, **then holds on.** Another interesting lizard is the black iguana (*e-gwah'-nah*), 4 feet long, of the southern and south western states. If it can escape it will not attack man, but when cornered, will become very angry, lash its tail and, with wide-open mouth, snap viciously at its enemy.

379. Horned lizards, usually called "horned toads," are fairly common in the desert regions of our western states. They are

four to six inches long, and of a mottled brown or tawny gray color. They love the hot, arid wastes of the desert where, at night, they burrow into the sand and remain until the heat of the next day's sun warms them again into activity. They

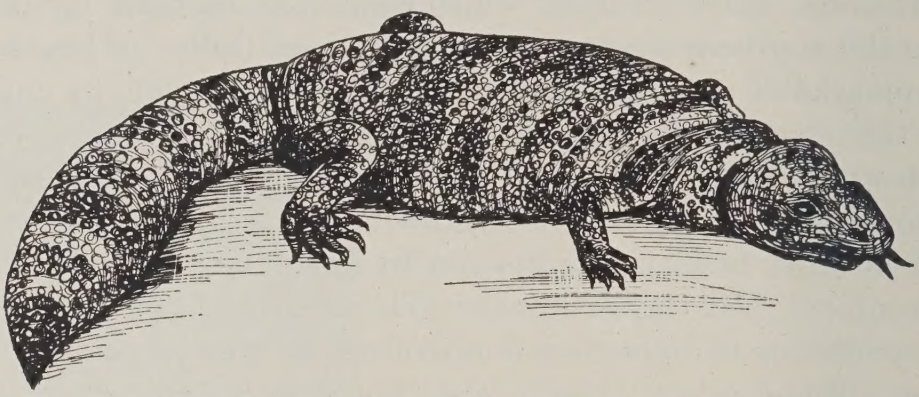


FIG. 175.—The Gila monster of our southwestern states is the only poisonous lizard in the United States. (*Corwin and Corwin.*)

scamper here and there, snapping up small insects with the tongue, much as does our common toad. When quiet, they are rather hard to see because, amid such surroundings, their tawny, grayish-brown color perfectly matches that of the sand.

FIG. 176.—By its scales, the horned toad is easily recognized as being a reptile. (*Holmes.*)

Before leaving this rather unusual group of animals we should mention the two-footed worm lizard, nine inches long, of Mexico, which has only two feet, the front pair; also the worm lizard, eight and one-half inches long, of Florida, which is not as well off, since it has no appendages at all. But why not take some

good book about lizards, such as *The Reptile Book* from your library and learn to know about some of the other equally interesting ones?

380. Alligators and Crocodiles.—These are the largest of our living reptiles. In fact, they are the nearest relatives of the large dinosaurs which lived ages ago. On account of the great similarity between alligators and crocodiles, they are grouped together as one order, the **crocodilia** (*krok-o-dil'-e-ah*). These animals are semi-aquatic, since they spend their lives in the swamps, rivers and lagoons of our southern states. As they

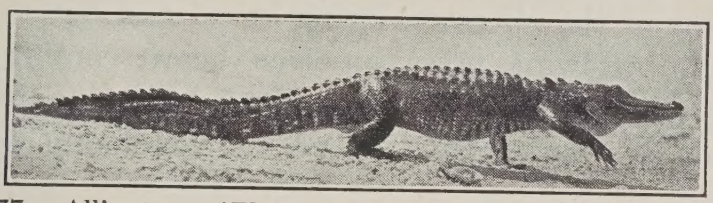


FIG. 177.—Alligator. (*The American Museum of Natural History.*)

cannot survive the rigorous winters, they do not live in the northern half of the United States.

381. They are large, lizard-like reptiles encased in a tough, leathery skin made up of coarse plates. The back is covered with several rows of horny plates. The head is flattened. The mouth, which is very large, is provided with a great number of sharp, pointed teeth. The tail is long and powerful; it is of great value in swimming. Some of the large forms are from eleven to twelve feet. One important internal characteristic, namely, the presence of a four-chambered heart—two auricles and two ventricles—should be mentioned because it is the first time that we have seen a heart containing this number of chambers.

382. The food of these animals consists of fishes, water birds, amphibians, and any unwary mammals which may venture too near their sharp eyes; for with a slow, gliding motion they approach their prey in or near the water so stealthily that it does not often sense the danger until too late to escape.

This method of food-getting calls our attention to the unusual adaptation of the crocodilia for killing their prey by drowning it.

In the back part of the throat is a large, movable flap of skin, which is closed after the prey is grasped, thus separating the mouth and throat cavities. This structure enables the reptile to continue breathing, with the nostrils out of water, while the prey is drowning. Then the food is quickly gulped down and there in the water it waits, dreamily, until the next victim comes along.

383. Unlike most of the other reptiles, alligators and crocodiles have eggs which are encased in hard, thick shells.

Crocodiles can be distinguished from alligators by the pointed snouts, those of the alligators being broad and flat.

The loud, bellowing noise so often heard coming from the southern swamps and lagoons at night is made by the alligator. It is a sound which, once heard, is not likely to be soon forgotten.

Interesting Projects

1. Make a list of as many different reptiles as you know. Can you name one distinguishing characteristic which they all possess?
2. Find out whether there are any poisonous snakes in your locality. What particular structures make certain species poisonous? Read all you can find about the poisonous species, so as to be able to identify one of them immediately, should you see one.
3. Which order of reptiles has the best protection? Describe the body covering, telling its shape and the units of which it is composed. Has this order any teeth? How does their presence or absence affect the food-taking habits?
4. Watch a snake crawling along. Is it easy to pick up? How does it gain a foothold so as to crawl along? What other animals are enemies of the snake? Do you think it can escape from its enemies less rapidly by not possessing legs?

Review

1. In what ways do reptiles differ from other animals?
2. How can a snake swallow prey that is larger than its own head?
3. How does the chameleon change its color?
4. What function is served among many snakes by the rapid darting out of their forked tongues?

Define

anti-venin serum
carapace
chromatophores
dinosaur
disarticulation of the jaws
fangs
matched scales
plastron
scutes
terrarium
tourniquet
venom
viviparous snakes

CHAPTER XXIII

BIRDS ARE HIGHLY SPECIALIZED VERTEBRATES

384. Who will ever forget his first sight of a bald eagle? Who will not pause a moment to watch that "fish hawk" or osprey make his "death plunge" from way up there in the skies, dropping like an arrow into the pond below? It gives one a real thrill as he sees the great bird rise out of the water with his fish, shaking his great dripping wings. What country boy doesn't rush into the house excitedly, to proclaim to the rest of the household that "summer is here because I have seen a barn swallow?" And, I might add, who will ever forget that weird, far-off call that came at night from out over the waters in the forest, as the loon or "great northern diver" uttered that ghostly, hollow, blood-curdling "Halloo-oo-oo" from its great throat?

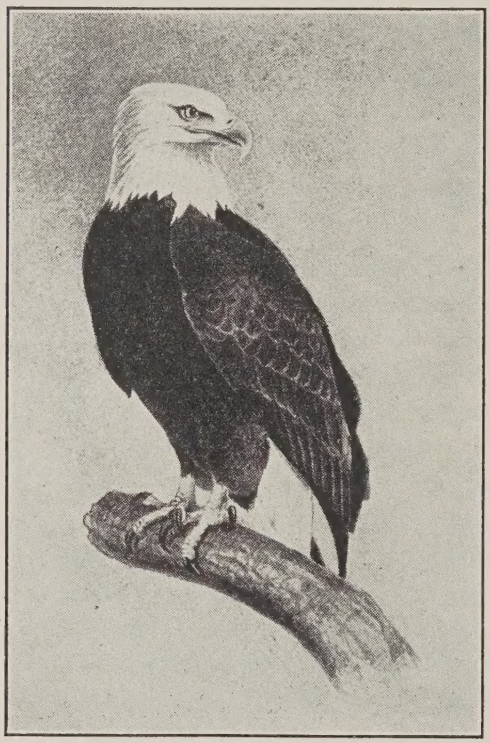


FIG. 178.—The Bald Eagle, our national bird. (*Courtesy U. S. Biological Survey.*)

Or maybe we have stood in the park or near a bit of woodland some spring evening, just at nightfall, and heard that beautiful song of the hermit thrush echoing again and again, or the clear, bell-like call of the wood thrush—the only bird that "hisses" at his own efforts. You have to be near to hear the hissing sound.

Have you experienced these pleasures? If so, you know what I mean, and that they are very real pleasures. If not, then you are the loser. You ought to get to know better your feathered neighbors. In the meantime we can study them scientifically in school.

385. In the whole world there are about three thousand species of birds, from the mighty ostrich that can not fly, to the tiny

FIG. 179.—The great blue heron is an expert fisherman. (*American Museum of Natural History.*)

hummingbird with a record of five hundred miles of flight across the Gulf of Mexico without stopping. In the United States alone there are seven hundred and sixty-eight different species of birds, nearly every state in the Union having at least two hundred different kinds. A few states, such as California, have over five hundred species.

386. These species naturally fall into a few large groups called "orders," each of which is very different from the others. As you learn them, you can classify those birds which you already know.

According to the American Ornithologists' Union, all birds are classified into twenty orders[1] a few of which are the following:

387. The Principal Orders of Birds

1. **Water Birds.**
   1. Loons (Gaviiformes—ga-ve-e-for′-mēs).
      Large, long-necked diving birds which feed on live fishes which they pursue under water.
   2. Herons, flamingoes etc. (Ciconiiformes—se-ko-ne-e-for′-mēs).
      Large, long-legged waders found at the edges of marshes, ponds, and streams.
   3. Ducks, geese and swans (Anseriformes—an-sēr-e-for′-mēs).
      Fairly large with flat bodies. Usually seen resting on the water. Broad bill with saw-toothed edge for straining small particles of food from the water.
   4. Sandpipers, plovers, etc. (Charadriiformes—kah-ad-re-e-for′-mēs).
      Fairly small shore birds. Usually seen on the shore or in shallow water hunting for food. Peculiar fluttering wing motion when flying.

388.

2. **Land Birds.**
   1. Vultures, hawks, and eagles (Falconiformes—fal-ko-ne-for′-mēs).
      Usually large, smooth-feathered birds of prey. Hooked beaks and claws.
   2. Grouse, quails, and turkeys (Galliformes—gal-e-for′-mēs).
      Fairly large scratching birds. Nearly always seen on the ground.
   3. Owls (Strigiformes—Strij-e-for′-mēs).
      Varying in size from medium to large birds of prey. Fluffy feathers. Hooked beaks and claws.
   4. Kingfishers (Coraciiformes—kor-ah-se-e-for′-mēs).
      Fairly large, slaty-gray, fish-eating birds. Large, long beaks with which they catch their food by diving for it.
   5. Woodpeckers (Piciformes—pis-e-for′-mēs).
      Climbing birds, usually seen on the trunks or limbs of trees. Their predominating color is black. Two toes in front, two in back.
   6. The Perching Birds (Passeriformes—pas-er-e-for′-mēs).
      Sparrows, warblers, finches, flycatchers, swallows, etc.

389. Characteristics of Birds.—What is a bird? A bird is a vertebrate which (1) has feathers; (2) has large hollow cavities

[1] The complete list of orders of birds will be found on page 537 of the Appendix.

in the bones; (3) has a four-chambered heart and a high body temperature; (4) reproduces by eggs, internally fertilized, and covered with a limy shell; (5) breathes by lungs throughout life; and (6) has no metamorphosis.

390. The bird is so essentially a flying animal that its whole plan and structure seem to have been designed for this purpose. You noticed that we did not list "flight" as an essential characteristic, because so many other creatures can fly. Most of the insects, bats, and a few of the pre-historic reptiles are known for their ability to fly; and even the so-called "flying fishes" can, by gaining speed, rise a very short distance into the air. But in the birds we have modifications for flight developed to a very remarkable degree.

391. Hollow bones form a rigid, yet light framework. A keeled sternum, or breast bone, offers a broad surface for the attachment of the wing muscles. Feathers are the ideal body covering for flight. They lie smoothly and do not offer resistance to the air. On cold days you may have seen a sparrow with its feathers all puffed out until the bird looked like a little ball. A dead-air space next to the body is thus produced, through which the heat of the bird's body does not rapidly escape. Because of their warm coating of feathers birds are not chilled in high altitudes.

Continued flight for long distances, as well as ordinary flight, is vigorous exercise, requiring the expenditure of a great amount of energy; hence birds are voracious eaters. They often consume their weight of food daily. Because of the rapid oxidation of all this food, their body temperature is the highest of all vertebrates.

392. The different species of birds vary considerably according to their habits and needs. Gulls and other birds which spend much of their lives in the air have long, powerful wings for sustained flight; while such species as robins and bluebirds do not need wings of this type. If you have ever watched a robin standing out on the lawn with his head cocked to one side, you have noticed that he appears to be listening to something. Soon he takes a hop forward, then to one side, and having located his

dinner, drives his bill into the ground. Out it comes with a live earthworm. To do this the robin needs, and surely has, a keen sense of hearing.

393. On the other hand the vultures and hawks need, and indeed possess, very keen sight, since they do their hunting from a greater distance. Other forms such as grouse, ducks, and

FIG. 180.—Notice the broad, keeled sternum or breastbone of the hawk, adapted for the attachment of the wing muscles.

quails which must rise into the air rapidly from the ground for a quick "get-away" from their enemies, possess short, strong wings, well adapted for that purpose. One might continue at some length, discussing the wing adaptations of many other species.

394. But of special interest are the beaks and feet of birds. These parts tell us much about the bird itself. Notice the hooked beak and the powerful claws of any hawk or owl. Do you doubt that these birds are very successful at grasping and holding the mice, snakes, and other small living animals which make up their

FIG. 181.—The beaks of birds are adapted for getting the kinds of food that they eat. (Left to right: Curlew, a shore bird; Duck, a "bottom feeder"; Woodpecker; Grosbeak, a seed eater; Hawk, a bird of prey).

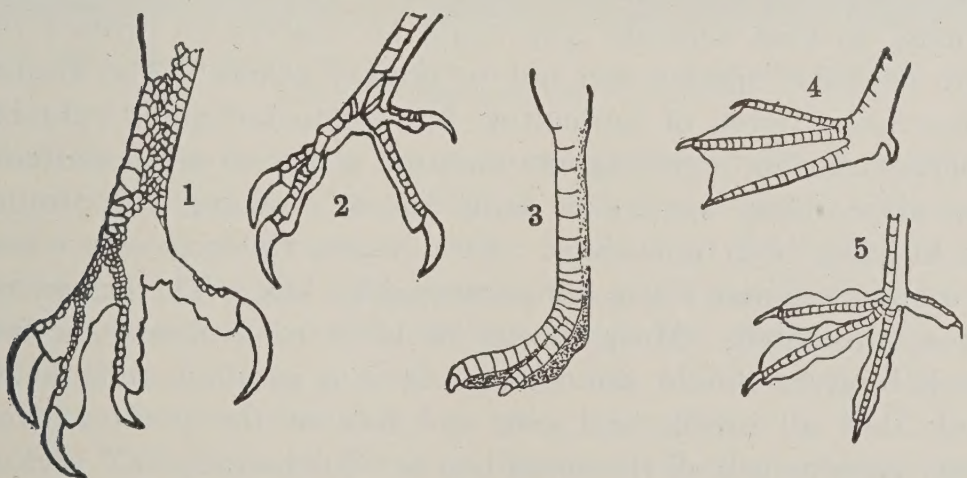


FIG. 182.—The feet of birds show adaptations for different functions. (1) Hawk, (2) Woodpecker, (3) Ostrich, (4) Duck, (5) Grebe. (*Holmes.*)

bill of fare? Have you ever noticed the very long legs and beaks of the wading birds, such as the herons and bitterns that stalk their prey in the shallow waters? Did you ever watch one of them as it slowly crept up on an unsuspecting frog or fish, at the edge of a pond? Both the bird and the frog were in plain sight of each other all the while. Soon the bird, having approached near enough, with lightening speed drove that long bill straight down at its prey. Usually the bird was successful. You will want to see them do this next summer; in fact if you once begin to look for things of this kind, you will find many pleasant hours of outdoor enjoyment awaiting you.

395. Economic Importance.—For the most part birds are either beneficial or injurious, according to the food they eat. One harmful species is the sharp-shinned hawk which feeds largely on smaller, beneficial birds. Certain other species are both harmful and beneficial. An example of such birds is the bobolink which feeds on rice during the winter months in the south, and also destroys quantities of weed seeds during its summer stay in the north. But most species of birds are distinctly beneficial because of the fact that they feed on weed seeds and injurious insects. Among these are the sparrows, woodpeckers, swallows, and warblers. Much study has been necessary to determine which species of birds are beneficial and which ones are harmful to man, so that suitable laws could be enacted to protect the more desirable species and not to protect others. The United States Department of Agriculture has conducted much valuable experimentation, including examination of the stomach contents of a great many species of birds whose economic importance has hitherto been uncertain. As a result, those species which do more good than harm are protected by law. The others are not so protected. Most species of birds are valuable, a fact which hunters should remember. It is a common mistake to think that all hawks and owls are foes of the poultry yard. Many persons call all the small hawks "chicken hawks," and all the large ones "hen hawks." This loose way of naming them is as untrue as it is unscientific. Only three or four species of

hawks, including the sharp-shinned hawk, the cooper's hawk, and the goshawk (*gos'-hawk*), are really harmful. The sixteen to eighteen other species are beneficial.

396. We are dependent on agriculture for our supply of food. Think of the vast hordes of insect pests which destroy so many of our field and garden crops! How many more food crops would be destroyed were it not for the birds which feed upon these insect pests! A never-ending battle is being waged between the

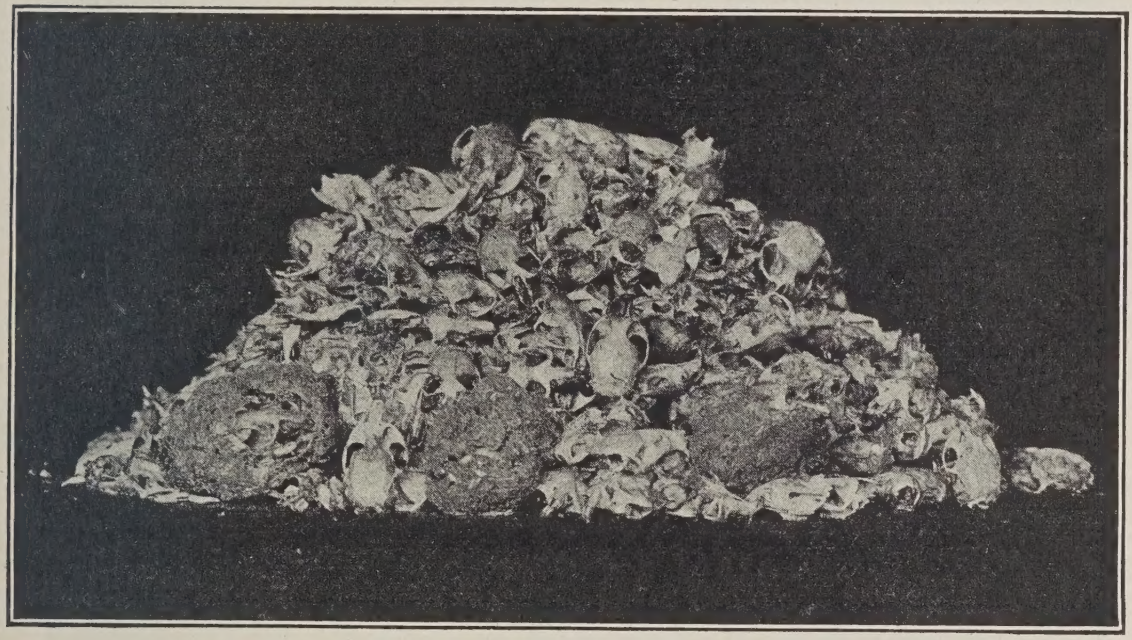


FIG. 183.—Many rodent skulls under an owl's roost show that this bird is more beneficial than harmful. (*Atwood.*)

birds and the insects. Farmers would eventually be unable to supply our people with sufficient food if our fields and woods had to be kept sprayed in order to do what the birds are now doing in keeping down the insect pests. We should make known our position as good citizens by telling other persons the importance of not killing any species of birds which, being protected by law, are thus proclaimed as being beneficial.

397. The Place of Birds in Nature.—How much less interesting would be our walks through the fields and woods if we did not occasionally see some new species of bird! That well known

naturalist, John Burroughs, in speaking of a friend, said "the groves and fields through which she used to walk with only a languid interest, were now completely transformed to her and afforded her the keenest pleasure; a whole new world of interest had been disclosed to her; she felt as if she was constantly on the eve of some new discovery; the next turn in the path might reveal to her a new warbler or a new vireo."[1]

In recent years many bird study clubs have been formed in all parts of the country. Bird-banding organizations, likewise, have sprung up, and are increasing in numbers and activity. Much attention is now given to the study of birds in our public schools and in such organizations as the Boy Scouts and the Girl Scouts. This increasing interest in "our feathered neighbors" is plain recognition of the need of our knowing the commoner kinds of birds that visit our lawns and gardens. Their bright colors and their cheery songs remind us that

"The year's at the spring
And day's at the morn;
Morning's at seven;
The hillside's dew-pearled;
The lark's on the wing;
The snail's on the thorn;
God's in His heaven—
All's right with the world!"

—*Robert Browning.*

398. Migration of Birds.—Bird migration has long been a topic of discussion. How can a bird tell north from south? How and when did the habit of migration begin? That eminent authority on birds, Dr. Frank M. Chapman, in his *Handbook of Birds of Eastern North America*, on pages 56 and 57, where he refers to the glacial period, quotes Allen as saying "With the later refrigeration of the northern regions, bird life must have been crowded thence toward the tropics, and the struggle for life thereby greatly intensified. The less yielding forms may have become extinct; those less sensitive to climatic changes

[1] From *Bird Neighbors*, by Neltje Blanchan, copyright 1926 by Doubleday, Doran & Co., Inc.

would seek to extend the boundaries of their range by slight removal northward during the milder periods of summer, only, however, to be forced back again by the recurrence of winter. Such migration must have been at first 'incipient and gradual,' extending and strengthening as the cold-wave Ice Age receded and opened up a wider area within which existence in summer became possible. What was at first a forced migration would

FIG. 184.—Ducks migrating. (*Courtesy U. S. Biological Survey.*)

become habitual, and through the heredity of habit give rise to the wonderful faculty which we call migration."

399. Some species migrate at night; others fly by day. With most birds the migration flight is taken leisurely, as they stop to feed and rest while on the way. A few species fly very rapidly. The arctic tern, which migrates eleven thousand miles every spring and autumn between the arctic and the antarctic regions, is said to maintain an average daily speed of seventy-five miles

an hour. The greatest recorded speed of birds is that of a large eagle in Scotland which flew one hundred and twenty miles an hour; also of a large vulture which flew for several minutes ahead of an airplane traveling one hundred and ten miles an hour.

400. The homing instinct is quite common among most of the higher animals, and so, with the coming of spring, it is not strange that birds which have migrated southward return north again.

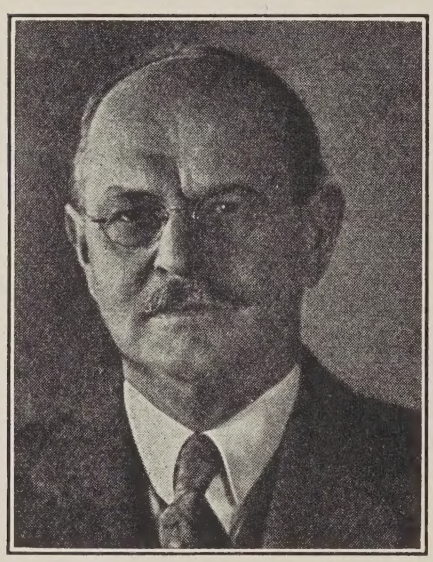


FIG. 185.—Frank M. Chapman (1864–), curator of birds in the American Museum of Natural History, has made a life study of birds and their habits, and is an outstanding authority in this field. (*American Museum of Natural History.*)

The placing of light metal bands[1] on the legs of birds before releasing them, has been a means of learning much about the routes taken in migration, the feeding and resting habits during migration, and the length of time required for the flight.

401. Not all ornithologists[2] (*or-nith-ol'-o-jists*) agree as to how birds are able to keep their direction while migrating. Some of these persons believe that birds possess a sort of sixth sense not shared by man, which enables them to hold to their course. Others who have experimented with such forms as homing pigeons, contend that birds must be fairly familiar with the country over which they are to fly before they can maintain their direction safely.

The power of birds to see at a distance is often underestimated, and no doubt the elevation at which many species migrate (an altitude of from ¼ to ½ mile) is a great aid in keeping their

[1] Each of the light-weight aluminum bands bears a number which is recorded by the Biological Survey at Washington, where the name and address of the observer are kept on file together with the species of bird and the place and time of banding.

[2] The name given to students of birds.

direction, since this elevation permits a wide range of vision over the country beneath them. There is general agreement among ornithologists that a large proportion of the migration routes are over the river valleys which extend generally north and south.

402. Large numbers of birds meet their death while migrating. Thousands of the night-fliers are killed by crashing into light-houses; others fall victims to numerous enemies; and still others lose their way and perish. Although often hazardous to the individual birds, migration has proved to be beneficial to the various species, and we should remember that nature many times seems to regard the welfare of the species much more highly than that of the individual.

403. According to migratory habits, birds are classified into four groups. The species which are thus classified naturally vary for different sections of the country, but for the northern half of the United States the following species are typical:

(*a*) *Summer Residents.*—These include such species as robins, bluebirds, orioles, and most species of sparrows and warblers. These and many others arrive in the northern states in the spring and spend the summer, flying south again with the return of cold weather.

(*b*) *Winter Visitants.*—The snowy owl, goshawk snow buntings, pine grosbeaks (*grōs'-bēks*) horned larks, and others which nest in Canada and points further north, are often driven southward because of a lack of food at times during the cold winter months, and it is at these times that we see them, before they return northward again.

(*c*) *Permanent Residents.*—Such species as English sparrows, blue jays, chickadees, and nuthatches are with us throughout the year.

(*d*) *Transients.*—Canada geese, arctic terns, certain species of ducks, and several species of warblers are among those that spend the summer in Canada and other parts of the north, migrating to points much farther south during the winter. We see these birds only as they stop to feed and rest during their migration.

404. Bird Homes.—As we approach the wide variety of places selected by birds for their nests, we are reminded of Lowell's lines:

"And there's never a leaf nor a blade too mean
To be some happy creature's palace."

Birds nest in all conceivable sorts of places. By far the greatest number of them build their nests in trees or on the ground. Some others nest in very unusual places. The following examples

FIG. 186.—A screech owl. (*Holmes.*)

will serve to illustrate these statements: the whippoorwill seldom builds any nest, but lays its two eggs on a flat rock, and has been known to nest on the flat top of an apartment house in the city. The screech owl, which nests in January or February while the snow is still on the ground, merely seeks out a deserted woodpecker's hole in some tree, in which to make its home. Eagles usually nest high up on the cliffs, safe from most of their enemies. The kingfisher and the bank swallow excavate a tunnel from three to five feet long into the face of a high sand bank and raise their families there. The Baltimore oriole weaves its beautiful deep basket nest, made of strings, horse hairs, and dead grasses,

and suspends it from the tip branches of the elm or some other tall tree where it hangs all summer long, secure from most enemies. But why does the great-crested flycatcher usually hang a discarded snake's skin at the edge of its nest in that old hollow tree? Few nests are found without it.

FIG. 187.—Nest and eggs of Brewer's blackbird. Like most of the other blackbirds it nests in the swamps. (*Holmes.*)

405. And so we could go on for some time, telling about the cowbird, which lays its eggs in the nests of smaller species of birds; the chimney swift, which cements its shelf-like nest to the inside of a chimney; the great blue heron, which nests in colonies in the tops of the tallest trees; and many others, which make their homes in equally interesting places. But why not read the bird books in your library, or better still, study nature as well as books, and learn about bird homes for yourself?

406. The Earliest Birds.—Fossil skeletons of the earliest birds which may be seen today in our larger museums, show that these birds were quite unlike ours today. They had long, snake-like necks, reptile-like teeth, a poorly developed breast bone, and

claws on each of the three free fingers. There were also large steering feathers extending outward on each side of the tail.

407. Parental Care.—Everyone is more or less familiar with the care and protection which nearly all birds give to their young. Who has ever watched barnyard fowls and has failed to observe

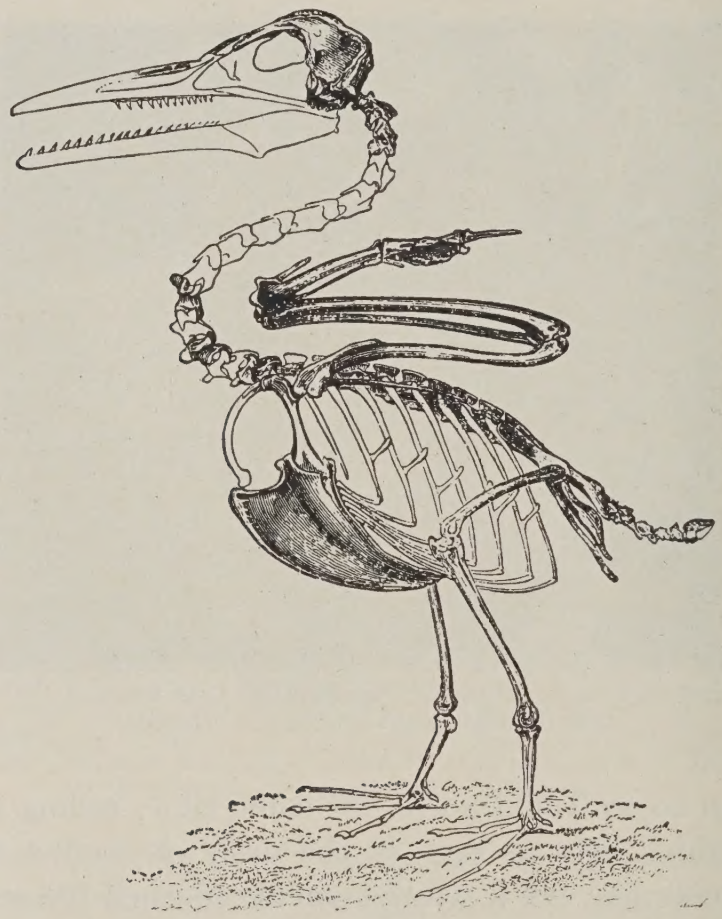


FIG. 188.—The Ichthyornis, a toothed bird of prehistoric times. (*After Marsh.*)

the care of the mother hen as she utters that food call, or the danger call, or the brooding call, and has seen the immediate response of the little ones, as they crouch to the ground or run to safety as that call may require? Who has ever visited a nest of young kingbirds without being "threatened" by the fierce swoops made at the intruder's head by the parent birds? Why does the ruffed grouse impersonate the cripple as she hobbles

away from her young into the woods, dragging one wing and, as one observer expresses it "has rheumatism in every joint," except to lure her enemy away from those little fluffy, brown chicks for which she readily risks her own life? Dr. Allen[1] mentions a house wren which in the daylight hours of one day came with food to her nest of young, 1217 times. We have not seen such care among any of the lower animals. Such behavior commands our respect.

FIG. 189.—The English sparrow often drives away our more desirable song birds. (*Courtesy U. S. Biological Survey.*)

Some of Our Common Birds

408. English Sparrow.—The English sparrow, sometimes called the house sparrow, is, in most of our cities, the commonest form of bird life. Before the year 1850 there was none of these birds in this country. As the name implies, they came from England where they were valuable because they destroyed such large numbers of canker worms. They were imported into the United States to get rid of that insect pest, but here they found a much easier existence by merely picking up grain and other food in our village and city streets; and almost at once stopped eating canker worms, and thereby ceased to be beneficial.

409. By nature the English sparrow is a born fighter. Olive Thorne Miller calls him "a ruffian in feathers." Thornton Burgess calls him "Bully, the English sparrow." Another bird student says of them: "They are not birds; they are little beasts." You will see them on your way home from school almost any

[1] *The Book of Bird Life*, page 188, by Dr. Arthur A. Allen, D. Van Nostrand Co.

day if you will but look for them. Noisy and boisterous, fighting each other and madly hopping about after any stray particles of food that may be in the street or in the gutter, they keep up their incessant twittering, enlivened only by an occasional fight.

Three or four broods are raised each year, the nests being placed in eaves troughs, in attics and vacant buildings, and frequently under the awnings above the sidewalk.

The English sparrow, which was brought here for the good that he might do, has failed to "make good," and because of the fact that he drives away our beautiful and more valuable song birds, he has long since worn out his welcome.

410. The English Starling.—This species, like the last, was also imported. In 1890 and 1891 fifty pairs were brought from England and turned loose in Central Park, New York City. These birds have demonstrated their ability to fight their enemies, to reproduce rapidly, and to live in almost any kind of surroundings. In this sense they are a very successful species. The English starling is a little larger than the English sparrow. It can easily be identified and distinguished from blackbirds by its very short tail and light-colored bill, also by the fact that its feathers are more or less spotted or mottled. In some kinds of light there can be seen an iridescent sheen around the neck, which sometimes looks purple and sometimes appears greenish in the sunlight. Starlings live mostly in the cities where they congregate in flocks of hundreds, and at nightfall many church spires and the tops of other public buildings, not already screened, seem to be alive with these birds. They have no song other than a monotonous chirp. They breed rapidly and, like the English sparrow, are increasing in numbers.

411. The American Crow.—It has been said that the crow has been "weighed in the balance but *not* found wanting." Because the crow eats a great many insects, especially grasshoppers, most bird students do not feel that he does any more harm than good. Crows are not protected by law as are our song birds, nor is there a bounty offered for killing them. In some parts of the country they do much good by the numbers of insects that they

destroy, but they also do much harm. Crows have a fondness not only for the eggs but even for the young of other species of birds.

412. Have you ever had an opportunity to watch crows stealing newly planted corn in a corn field? They station one sentinel on guard up in the top of a tall tree where he can watch for the approach of danger. Then the others get to work on the corn. A sharp call from the sentinel will put the whole group to instant flight. Crows usually nest in the tops of evergreen trees, showing a preference for pines. The nest, which is a bulky affair made of twigs and sticks, is often placed forty to fifty feet from the ground. The four or five eggs, which are about one and one-half inches long, are greenish in color, and are spotted and streaked with brown and black. In most parts of the country crows can be seen at almost any time of the year, although large numbers of them do migrate south for the winter.

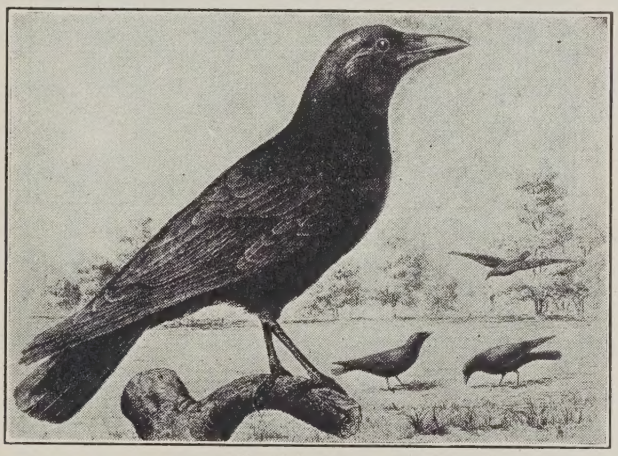


FIG. 190.—The common crow. All things considered, the crow probably does more good than harm. (*Courtesy U. S. Biological Survey.*)

413. American Robin.—One of our best known birds is the robin. Even in our early childhood he came to us in our story books. He is one of the commonest birds about our lawns and gardens, and seems to prefer to live near man. Every old orchard generally has a pair of robins that nest in it. The nest is a deep cup made of mud and bound together by dead grasses.

Here the four or five blue eggs are laid, and hatch in thirteen days into small but very hungry birds.

FIG. 191.—Robin feeding young. The home-building habits of birds and their care of the young may be compared to similar activities among human beings. (*U. S. Bureau of Biological Survey.*)

The adult robins are ten inches in length; the head is black; the sides and back are grayish slate; the throat is white and the breast, rufous red; hence the name, "robin red breast."

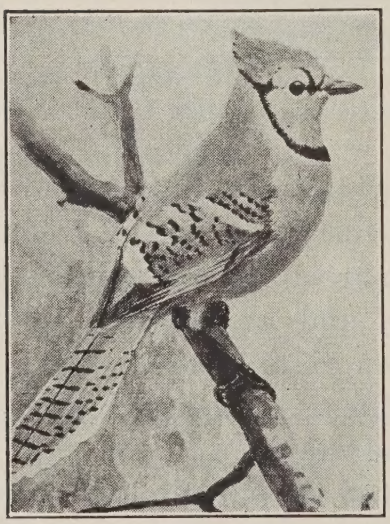


FIG. 192.—Blue Jay. "Fine feathers do not always make fine birds." (*U. S. Bureau of Biological Survey.*)

The robin is one of the earliest spring arrivals from the south, and his appearance, especially in the country, is always a welcome sight. His food is made up, for the most part, of earthworms, although during the summer months he eats cherries and berries of different kinds. His cheery presence and even his well known "rain song" always serve to brighten the day, and account in a large measure for his being a universal favorite.

414. The Blue Jay.—The person who said that "fine feathers do not make fine birds," was certainly speaking of a blue jay.

"A villain of the deepest dye" is the way one author has described him. Blue jays are beautiful birds. We enjoy looking at them, forgetting for the moment their very bad traits. They are permanent residents, living with us the whole year through, and were it not for the spring months when they rob other birds' nests—for fresh eggs and tiny young birds are especially choice morsels to the blue jay's taste—they would be very popular.

Up among the branches but not far from the ground, the blue jay builds his coarse nest of twigs and grasses, and guards his own eggs and young as zealously as he hunts for those of his neighbors.

415. The Bluebird.—"The harbinger of spring," azure blue above, throat reddish brown, white beneath—this is the bluebird.

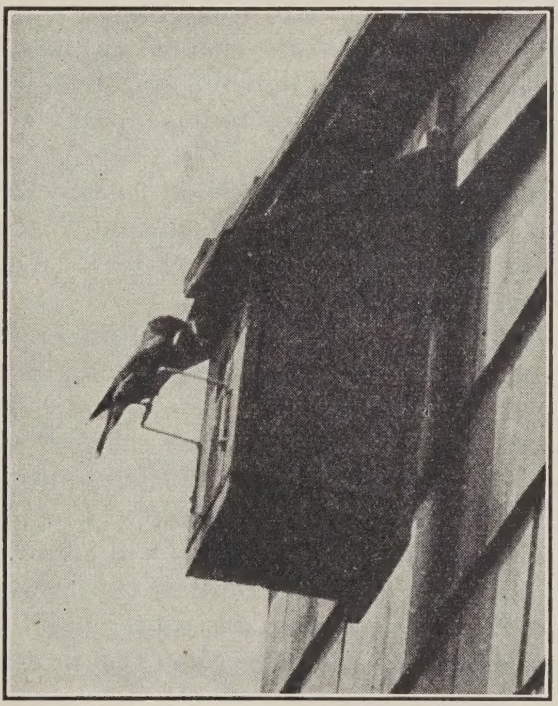


FIG. 193.—"Moving in." Bluebird entering house with a load of straws.

In most localities he is our earliest spring arrival from the south. The bluebird is a little smaller than the robin, being about seven inches long. He feeds on insects and weed seeds. His home is usually in a hollow fence post or bird house. The four or five pale blue eggs, which are more nearly round than those of

most birds, are beautiful. This species is a quiet, attractive addition to our lawns, gardens, and fields, and we are fortunate if we have a pair of bluebirds nesting near us.

When the bluebirds begin to congregate in flocks every autumn and to utter that faint twittering call which perhaps you have heard, it makes us realize that summer is over, and that most of our birds will soon be migrating southward.

Interesting Projects

1. Learn to know the birds of your neighborhood, and identify as many of them as possible. Ask your teacher for help in doing this. Get acquainted with the bird books in your school and public libraries. Start a card index of the birds you can name correctly, making out a card for each species observed. Each card should have a reasonably accurate description of the bird. Try to add such data as its nesting place, materials used in building the nest, number of eggs laid, length of incubation period, kinds of food fed the young birds, and any other notes of value and interest.
2. Make a list of the winter birds observed in fields, vacant lots and in the parks during the winter months. Try to find out what the birds are doing there. What do they feed on during the winter? Which of these species live there throughout the year?
3. By consulting various Department of Agriculture bulletins in the library find out which common species of birds in your locality are not protected by law. Learn also why they are not protected.
4. Construct one or two bird houses, making the roof water tight and the entrance a few inches above the floor. Fasten in place securely, well up out of the reach of small children and cats. If well made and wisely located, these houses will be occupied and will afford you a good opportunity to study the home life of the birds at the nesting season.
5. Well-stocked feeding trays during the winter months, and bird baths during the summer, will likewise repay you well in feathered visitors.

Review

1. What pleasure may one derive from studying birds in the fields and woods?
2. About how many species of birds are there in your own state?
3. According to what habits does the economic importance of any species of birds depend?
4. How do some authorities believe migration among birds first started?

5. In general, how can we distinguish a seed-eating bird from an insect-eating bird?
6. What adaptations for food-getting do we see among the hawks and owls, the herons and bitterns, the vultures, the gulls?
7. Discuss the economic importance of birds, giving specific examples.

Define

agriculture
bird banding
biological survey
ice age
keeled sternum
migration of birds
ornithologist
permanent residents
summer residents
transients
winter visitants

CHAPTER XXIV

THE MAMMALS ARE OUR NEAREST RELATIVES

416. We human animals belong to the class of vertebrates known as mammals. Therefore this class appeals to us as being the most interesting of all the animals.

417. Characteristics.—What is a mammal? It is a vertebrate having all the characteristics of vertebrates in general and certain

FIG. 194.—The duckbill. This mammal lives in the water like a muskrat, but lays eggs. The nest is placed in a tunnel in the bank near the water. This animal is found in Australia. (*Atwood and Heiss.*)

others which distinguish it as being the highest type of vertebrate. (1) There are mammary or milk glands from which the young are fed. (2) The body is wholly or partly covered by hair. (3) There is a muscular diaphragm (*di'-af-ram*) used in breathing. (4) They have the most highly organized brain of all animals. These four characteristics appear only among the mammals and are known, therefore, as **distinguishing** characteristics.

Mammals bring forth their young alive (except in the case of the duckbill and the echidna), but so do certain reptiles, fishes and insects although the organs are not the same. Then too, they have a four-chambered heart as do also the birds and higher reptiles. Only among birds and mammals do we find warm blood, the body temperature of birds being the higher of the two.

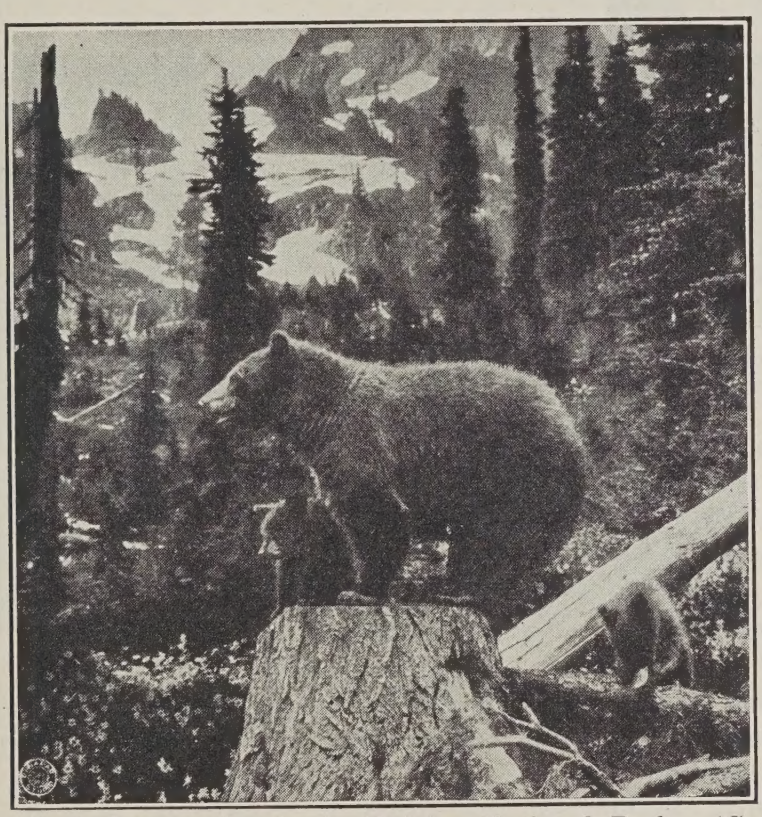


FIG. 195.—Black bear and cubs in Rainier National Park. (*Courtesy, The Milwaukee Road.*)

418. There are more than three thousand species of mammals in the world, nearly every state having dozens of different ones. Their success in life is largely due to the fact that they have a very well organized brain. In times of stress and strain, such as of local food shortage or the encroachment of their enemies, it is the mammals that migrate to safer quarters or to better feeding grounds.

419. Orders of Mammals.—Mammals have been classified, according to their structure, into several **orders.** These include the following:

1. Cetacea (se-tā′-she-ah)—whales, porpoises etc., *adapted for living in the ocean.*

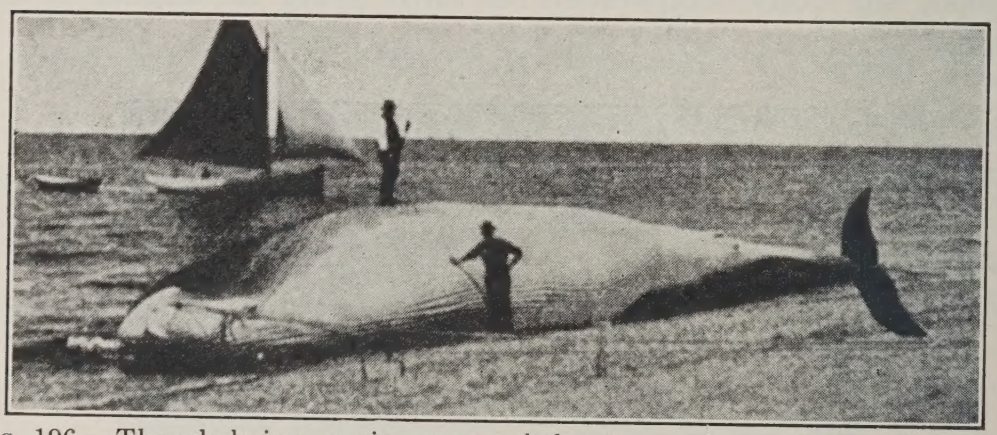


FIG. 196.—The whale is a marine mammal that can no longer live on the land. (*From True, "The Whalebone Whales of the Western North Atlantic."*)

2. Chiroptera (ki-rop′-ter-ah)—bats, *the flying mammals.*
3. Insectivora (in-sek-tiv′-or-ah)—shrews, moles etc., *the long-snouted insect eaters.*
4. Marsupialia (mar-sū-pe-a′-le-ah) (Marsupials)—kangaroo, opossum, etc. *Those mammals which carry their immature young in a pouch on the under side of the body until they are fully developed.*
5. Carnivora (Carnivores)—cat, fox etc., *the flesh eaters.*
6. Primata (pri-mā′-tah) (Primates)—man, monkey etc., *large-brained mammals having nails instead of claws. More or less upright posture when walking.*
7. Rodentia (ro-den′-she-ah) (Rodents)—squirrels, beavers, etc., *the gnawers.*
8. Ungulata (un-gū-lā′-tah) (Ungulates)—cattle, deer, etc., *the hoofed mammals.*

Of all these many and varied forms we shall study only the four most abundant orders.

420. Carnivores.—The carnivores include many of our pets, such as the dog and cat. They are the flesh eaters.[1]

[1] One theory for the hostility between dogs and cats is that ages ago, when both roamed wild, they were keen competitors for the same food.

Their most distinctive characteristic is their well-developed canine teeth. These teeth are strong and pointed for tearing the prey, which is normally chewed or torn apart enough to be swallowed as soon as it is killed. Another characteristic is the presence of pads on the lower surfaces of the toes. One very interesting carnivore which you will want to see in some museum is the saber-toothed tiger. These carnivores lived ages ago, and it is believed that they used their two largest canine teeth—one on

FIG. 197.—It is believed that the continued growth of the long stabbing teeth was the cause of the extinction of the Saber-toothed tiger. (*American Museum of Natural History.*)

each side of the upper jaw—for stabbing their prey. These teeth, through use, continued to grow larger and longer until for some reason—perhaps they were so large that the tiger could not open his jaws wide enough to take in food—this over-specialization proved to be the undoing of this species, for soon after the two stabbing teeth reached their immense size, several inches in length, the race became extinct.

Some of the commoner carnivores are lions, bears, seals, tigers, weasels, and foxes. Notice that certain of the carnivores, such as the seal, are adapted for living in the water.

421. The Fox.—A typical carnivore is the red fox. He is hunted and trapped for his attractive and valuable fur. Many are shot when they go too near poultry houses to steal live poultry

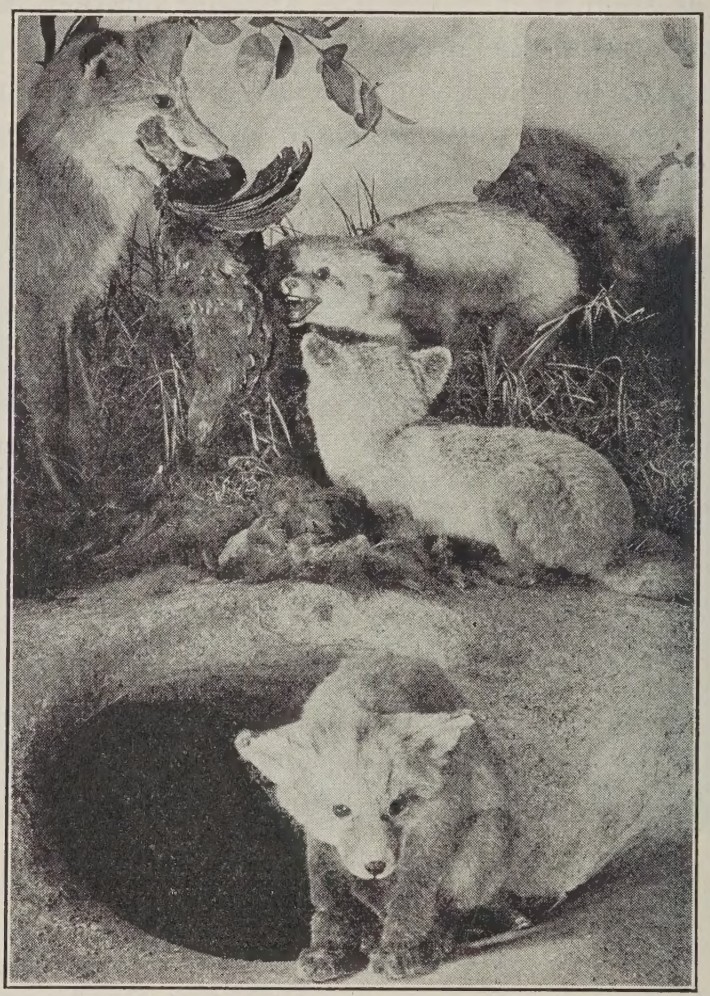


FIG. 198.—A fox group. The fox is one mammal which, despite continual hunting, is believed to be holding its own in numbers. (*American Museum of Natural History.*)

of all kinds. But despite this fact, his race is probably holding its own in numbers.

422. Did you ever have an opportunity to watch a fox when pursued by a dog? If in the woods, he will run out as far as possible onto some partly fallen tree and then jump as far as he can. While the dog is finding the scent again, the fox is off to a new start. His wits are very keen. If he chances to come to a

stone wall he will follow along the top of that wall, for he seems to know that the dog can follow him here only with difficulty. This strategy delays the dog and gives the fox a new lead. If he comes to a brook, he usually wades along in the shallow water, for instinctively he acts as though he knows that his enemy can not follow his scent here. In a word, it is the fox's marvelous instinct, developed through many generations, together with his speed, that makes us wonder at his apparent wisdom. There is no doubt that in many parts of the country these very qualities have long since saved his race from extinction.

FIG. 199.—Silver black foxes are now raised profitably for their fur. (*Canadian Government Photo.*)

423. The high prices which are paid for the fox's fur have induced many to go in for fox farming. There are today several hundred fox farms in the United States. Here, in carefully screened pens, the foxes are fed and raised in captivity. Sometimes the fox in captivity will eat from one's hand, but he never entirely loses his natural instinct to be free again and always makes his escape at the first opportunity.

424. Rodents.—Again it is the teeth which enable us at once to distinguish the rodents. The front ones on both jaws are chisel-shaped. They are known as **incisors** (*in-si'-zers*). They are the original "eversharp," since by the way they wear they are self-sharpening.

The hard outer enamel cuts across the softer inner portion, the dentine, the sharp edge of enamel being thus preserved and the teeth wearing themselves sharp. This self-sharpening is tremendously important, for all of the rodents get their food more or

less by gnawing. Equally important is the fact that the teeth grow continuously all through life so that they never wear out. Think of the beaver's gnawing down a tree for lumber for his dam and his house, as well as for bark to eat all through the long winter.

The hares, the jack rabbit, the cottontail and several other species have four incisors above and two below, but two incisors on each jaw are much more common. Some of the commoner

FIG. 200.—When getting materials for a dam, beavers sometimes cut down large trees.

rodents are the rats, mice, guinea pigs, muskrats, woodchucks, and squirrels.

425. There are a great many species of squirrels in different parts of the world, all of which are rodents. One interesting species is the flying squirrel, which is one of nature's gliders. Its name is rather deceptive, as this squirrel cannot fly. If you ever come across one when you are out in the woods, you will see him scamper up the trunk of a tree to quite a height; then he spreads his four legs wide apart, and the broad flaps of skin extending from the neck and front feet to the rear ones and tail form a sheet of skin which serves partly to bear his weight. Gliding off at an angle of about 45 degrees, he sails smoothly through the air. The higher he starts, the farther he can glide.

This is his method of escape from enemies, as well as his regular means of locomotion.

The common red squirrel is better known. He is a very alert, sleek, bright-eyed little animal. Although wary at first, he soon learns who are his friends, and after coming to a spot once or twice he allows himself to be fed and becomes a regular visitor. He is popular then, with all except the birds that may be nesting nearby. It is his own fault if he is no friend of theirs,

FIG. 201.—The red squirrel makes an interesting visitor.

because they have learned that he will eat their eggs or young if he finds them.

426. Ungulates.—These are the hoofed mammals with the well-developed molar teeth. You have always known them. They are either even-toed like the cattle and sheep, or odd-toed like the horse and zebra.

One of the interesting habits of certain ungulates such as the cow is the way they chew their food. There are no teeth on the upper jaw in front; hence, when grazing, they twist the tongue around the grass, and with an upward motion break it off with the teeth of the lower jaw. It is swallowed at once without being chewed and passes into the rumen, or paunch, where it remains for a time. Then the cud is regurgitated to the mouth where it is

ground by the well developed molar teeth. Again it is swallowed and after passing through two other regions, enters the true stomach. Such ungulates are known as **ruminants** (*roo'-min-ants*) from the name of the first stomach into which the food is swallowed. Giraffes, deer, moose, cattle, sheep, and many others possess teeth and a stomach designed for an herbivorous diet.

427. Perhaps the commonest forms of ungulates are horses, cattle, sheep, and hogs, because for centuries man has domesticated them.

Like all domesticated forms, these animals lived wild at one time. Their ancestors were the native wild horses that roamed the plains, the native wild sheep and the wild ox of Europe, and the wild boar also of Europe and Asia. Their contribution to civilization has been very great. After man domesticated them, his food supply was so much surer that he ceased to be a wanderer and turned to agriculture. The Bible frequently mentions the shepherds who watched their flocks, centuries ago, on the old hillsides and in the valleys of Asia Minor.

428. But let us consider two present-day forms, the bison and the deer.

When the white man first came to America, great herds of bison roamed over the plains of our western and mid-western states. They afforded an abundance of food as well as the sport of hunting them. It is estimated that even as late as the year 1860 there were as many as ten millions of these animals. But man killed them off too rapidly, and about twenty years ago their numbers had been so reduced that the race was threatened with extermination. Man, their former enemy, now came to their rescue, with laws protecting them and with national game reserves where they were allowed to live and breed in safety. A fine piece of work has been done in saving their race. Today they may be seen in nearly all of our large game reserves and national parks, and are more numerous than they have been for several decades.

429. The white-tailed or Virginia deer is another well-known ungulate. These animals live in the woods and forests instead

FIG. 202.—The bison was successful in its competition with all its enemies except man. (*Corwin and Corwin.*)

FIG. 203.—Deer in the Maine forest.

of the open country. They are much sought for food as well as for the sport of hunting them. In recent years they have been killed in such large numbers that all states have only a short "open season," when only one deer may be legally killed by each hunter. Several states have established longer closed seasons extending from two to five years, which allow them a chance to increase to their normal numbers.

430. Wherever the lumbering interests are encroaching farther and farther back into the forests, the deer likewise migrate northward ahead of them. Deer are sleek, graceful animals, shy and quiet, but ever on the alert; and their senses—especially those of smell, hearing, and sight—are through constant use developed to a high degree.

431. Primates.—Of all mammals the primates rank the highest, because of the very high degree of organization of the brain. Another factor of no little importance is that of upright posture. As long as an animal walks on four feet, it seems to remain much like its ancestors of centuries back, but once it assumes a standing position, walking on the hind legs, it has great possibilities of development. The head is held higher and there is greater vision over a larger field. The arms and hands become free to obey the will of the brain. The so-called "opposable thumb" allows the primates another distinct advantage, for it makes them able to grasp, hold, carry, and use objects of all kinds for all sorts of constructive purposes as well as for defense.

Man, being the only animal that can reason, is the outstanding primate. Man alone can regret lost opportunities and resolve to make better use of his future.

Other primates are the orang outans, lemurs, monkeys, gorillas and apes. In addition to the characteristics mentioned above, they have nails instead of claws.

432. Varied Environments.—All over the earth we find the mammals. In the frozen wastes of the north we see the polar bears, seals, and walruses in the icy water or out on the ice floes. As we go south into the temperate regions, we observe that the

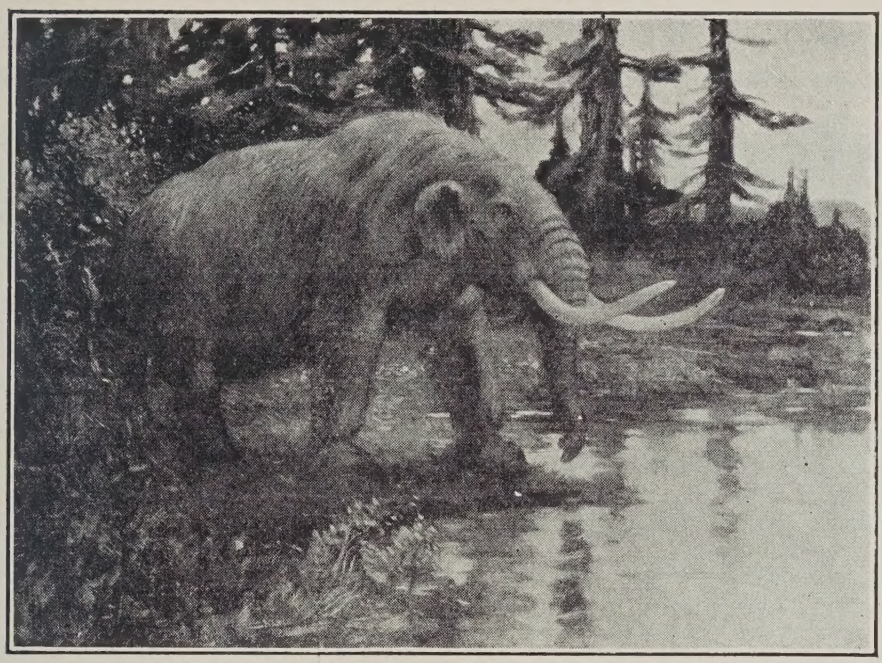


FIG. 204.—The mammoth, relative of the elephant, has long since become extinct. (*American Museum of Natural History.*)

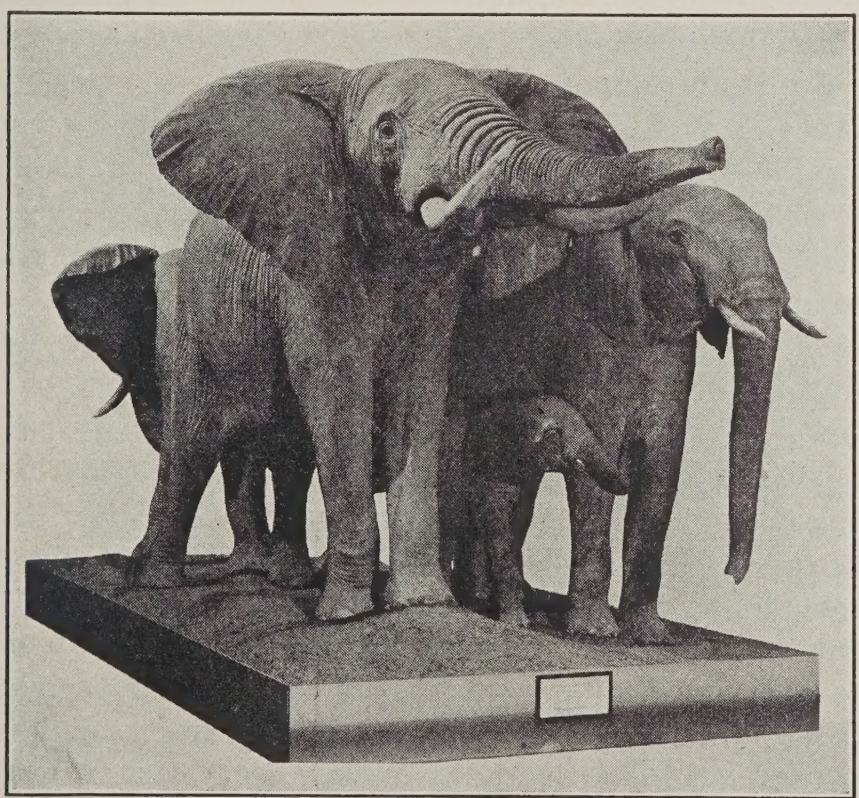


FIG. 205.—Elephant group. (*American Museum of Natural History.*)

numbers of mammal species increase rapidly, while in the torrid areas of the world the great variety of forms seems almost limitless. There are, for instance, the gazelles, and the sloths that always hang back-downward from the limbs of trees; there are also the zebras, the lions and tigers of the plains and jungles, and many other varieties of mammals. Continuing farther and farther south beyond the equator, the mammals which one finds more and more resemble those of the corresponding temperatures of the North. What does all this indicate? It shows a marked ability of these forms to become adapted to new and varied environments. They have been driven into the jungles, up the mountain peaks, and even into certain areas of the deserts; yet they have been neither crushed nor crowded out by the forces of nature. Few other animals living today have a record that can compare with theirs. Any individual or group that can move into a new land or new area and establish itself, matching its wits against hunger, drought, heat, cold, and enemies is on the way to racial success.

433. Economic Importance. 1. *As Food.*—An idea of the importance of mammals for food alone, may be gained from the 1934 Yearbook of Agriculture, which states that in 1932 there were 11,895,000 cattle; 8,650,000 calves; 22,945,000 sheep and lambs; 8000 goats; 74,021,000 hogs, and 100,000 horses slaughtered for meat.

2. *As the Source of Our Furs.*—At the present time furs form an important factor in our clothing, and every year the use of furs is increasing. Fashion dictates that furs shall be worn in each season, not merely during the winter, with the result that furs are becoming more scarce and therefore more valuable.

3. *As Beasts of Burden.*—In many countries various mammals are tremendously important in helping man to carry his loads. Elephants in India and the reindeer in the far North, where man depends on it alike for food and transportation, are good examples of beasts of burden. Horses and, in a lesser degree, oxen have for centuries provided man in the temperate zone with a means of transportation. And only recently, Roy Chapman Andrews of

the American Museum[1] depended upon his caravan of 125 camels to carry the provisions and supplies of the famous Second Asiatic

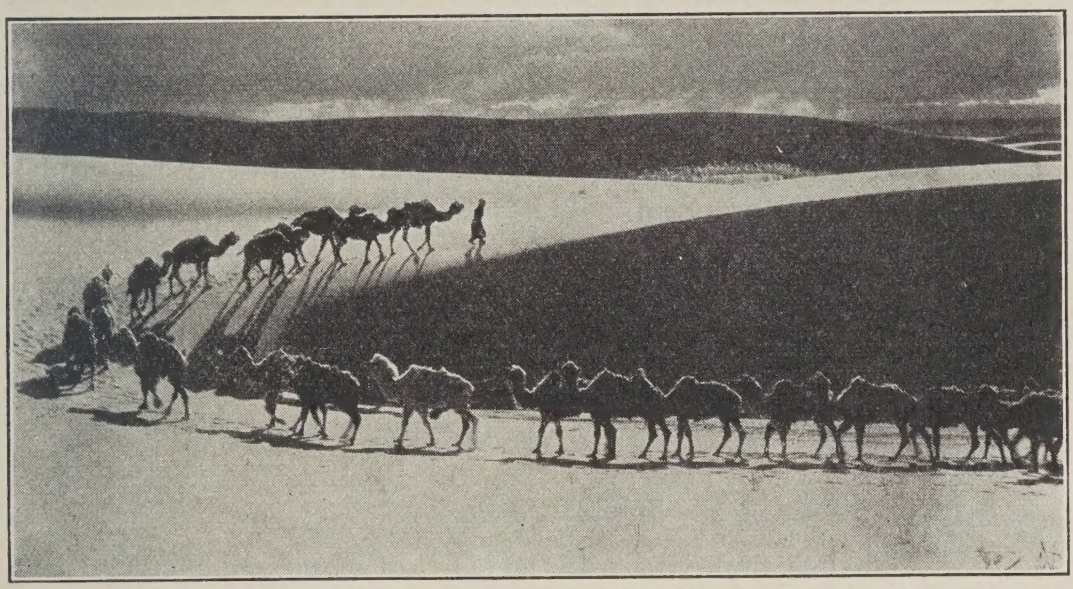


FIG. 206.—A caravan of camels. In crossing the deserts, camels are used today as they have been for centuries because they can withstand the heat and drought as can no other animal. (*American Museum of Natural History.*)

FIG. 207.—Eskimo dog team. (*Courtesy Harry Soule.*)

Expedition into the Mongolian desert. Dogs likewise, mean a great deal to the Eskimos and to the arctic explorers, who

[1] The American Museum of Natural History, New York, N. Y.

make long treks over the frozen wastes of the north where other domesticated mammals would be too slow and heavy.

4. *As Material in Medical Research.*—Many mammals including the horse, the sheep, guinea pigs, rats, and mice have been used in medical laboratories for the preparation of serums, for numerous blood tests, for determining the effect of certain new drugs before they can be used on human beings, as well as for studying cancer development and control. They have other important uses in the medical laboratories.

5. *As Companions to Man.*—Dogs have also been used for centuries to help tend the cattle and sheep, as well as for hunting wild game. All peoples recognize the dog as one of the finest pets, because of his comradeship, intelligence and loyalty.

Interesting Projects

1. From the public library look up the histories of such common mammals as the dog, cow, and sheep. Try to find out how these species came to be domesticated, and in what parts of the world it first took place.
2. Look up the long and interesting history of our common horse. What evidence can you find to show that at one time it was little larger than a small dog? Can you think of any advantages that have been gained by the changes in size and structure during the centuries while these changes have been coming about?
3. Visit some natural history museum and examine the skeletons of the prehistoric camels and horses. Have the changes been very gradual or did they take place all at once? Where did these early species live?
4. Work up a class report on some wild mammal such as the fox, showing what it feeds on, where it lives, how it escapes its enemies, and the reasons why it is increasing or decreasing in numbers.

Review

1. In what four ways may we distinguish the mammals from all other vertebrates?
2. To which order of mammals does man belong? Give three reasons for your answer.
3. What factors are causing many species of mammals to become fewer in numbers each year?
4. Which five species of mammals have probably contributed most toward advancing civilization?

5. What characteristics distinguish the rodents, the carnivores, the ungulates and the primates.

Define

canine teeth
carnivore
dentine
enamel
extinct
herbivorous diet
incisor teeth
instinct
molar teeth
primate
rodent
ruminant
ungulate

UNIT V

THE NUTRITIONAL PROBLEMS OF EACH PLANT AND ANIMAL VARY WITH ITS ENVIRONMENT

CHAPTER XXV

MOST PLANTS, NOT BEING ABLE TO MOVE ABOUT, MUST BECOME ADAPTED TO THE CLIMATE AND SOIL CONDITIONS WHERE THEY LIVE

434. One of the characteristics of most species of plants is their inability to move about from one place to another. In only one of the four main groups of plants is locomotion of any importance.

A glance at a simple classification of the plant kingdom will aid in making this point clear. Plants are classified as follows:

1. Thallophytes.
2. Mosses and liverworts.
3. Ferns and their allies.
4. Seed-bearing plants.

Let us now see what are the important characteristics of each of these four groups. A **thallus** means a simple plant body. So the group of thallophytes includes only those plants which have just that, a simple plant body—no stems, no leaves, no true roots, and no flowers. Perhaps you did not know that there are real plants so destitute. There are, and they are of two kinds: those having chlorophyll and those which do not possess it. The former are called **algae** (*al'-je;* sing., alga.); the latter are known as **fungi** (*fun'-ji;* sing., fungus). They are not strangers to you for seaweeds are algae, and toadstools and bacteria are examples of fungi.

435. Algae.—Algae are defined as being green plants of simple structure, which live in water or moist places. Very likely you have noticed the fine powdery growth so often seen on the north side of trees. This is made up of millions of tiny, one-celled **pleurococcus** plants. They have no stems, no leaves, no roots, and no flowers. More than that, they are microscopic. But not all algae are so small. Algae vary greatly in size. Some are so small as to be invisible to the naked eye; others, like the **giant kelp** of the Pacific coast, sometimes grow to be several hundred feet in length.

All the algae contain chlorophyll. This fact is to be remembered, since we speak of the "red algae" and the "brown algae" as well. In these last-mentioned groups, the chlorophyll is obscured by the presence of various kinds of pigment matter which gives them the red and the brown colors.

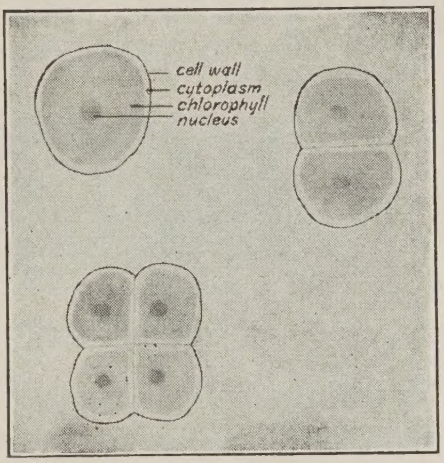


FIG. 208.—Pleurococcus, a common one-celled alga.

436. When algae grow in the water, they usually live at the surface where the light is strongest. On land, they are most abundant on the bark of trees, generally on the north side, for here is more shade and moisture. Frequently they will be found growing on the north side of wooden roofs and in many other similar places where there is shade and moisture. Algae are water-loving plants and absorb their moisture through the cell walls; hence they are not protected by water-proof **cutin,** (*kū'-tin*) as are many of the higher plants, to guard them against evaporation. For this reason, algae dry out very quickly and die unless they remain moist.

Perhaps you have seen small green masses of delicate threads floating in some pond or swamp. Often there are bubbles of gas entrapped among the threads. These masses are often called "pond scum" or "frog spittle"—rather poor names, since

they are thread algae and the "air bubbles" are bubbles of oxygen gas formed by photosynthesis (See page 53). Each of these threads is a complete plant. Fig. 209 shows the structure of **spirogyra,** one of these forms. The cells are elongated and the chlorophyll is attractively arranged in long spiral bands. When seen under the compound microscope, these bright green spirals are very conspicuous and easily serve to identify spirogyra, one of our commonest thread algae.

Among the many forms of algae reproduction takes place in three different ways. Such forms as pleurococcus reproduce

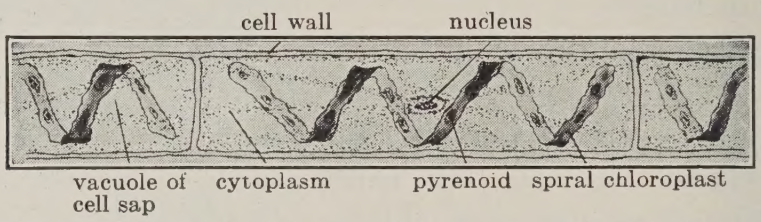


FIG. 209.—Spirogyra, one of our common thread algae.

by simple cell division or fission; spirogyra and other thread algae conjugate as well as reproduce by fission; while such forms as seaweeds reproduce by fertilization.

437. Conjugation of Spirogyra.—Simple cell division in spirogyra results in each thread of the alga becoming longer. It does not provide for new plants—for new threads being formed. They are produced by conjugation. When two of the threads in the tangled mass lie opposite to each other, each of them develops an enlargement somewhat resembling a bud. These projections increase in size until a bridge is thus formed connecting one or more pairs of opposite cells. This bridge becomes hollow, and the entire contents of one cell flow across through the connecting tube uniting with the contents of the opposite cell. There is no exchange of protoplasm. The resulting cell, formed of the contents of the two cells, is called a zygospore (*zi′-go-spōr*) or zygote (*zi′-gōt*). This zygote is a new reproductive cell. Around it is a membrane which soon breaks away from the parent plant and floats about in the water until, in the warmth and sunshine, it grows and starts dividing, and soon a new thread alga is formed.

Conjugation takes place commonly in the spring or in the autumn when conditions are unfavorable for the plants, such as drought or cold, and apparently there is need of more individuals being produced.[1]

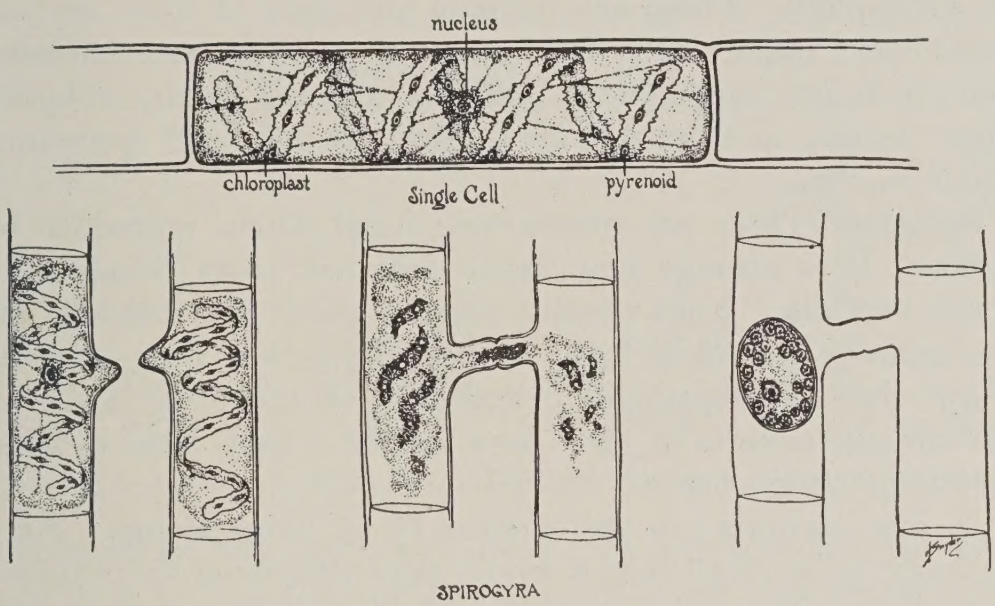


FIG. 210.—Conjugation in Spirogyra. The connecting tube forming, (left). Contents of one cell flowing across to unite with contents of opposite cell, (center). The zygospore, resulting from the fusion of the protoplasm of the two cells, (right). (*Copyright by General Biological Supply House, Chicago.*)

438. Other common forms of algae are Zygnema (*zig-ne'-mah*) and Oscillatoria (*os-il-at-o'-re-ah*). The latter has a peculiar waving motion to and fro in the water, somewhat like the slow swinging of a pendulum. The rockweed, Fucus (*fū'-kus*), so abundant along the ocean shores, and the various kinds of kelp, are all algae.

Algae have some economic importance. They usually get into aquaria and form a dark greenish coating on the sides of the glass which has to be scraped off. Sometimes they get into public reservoirs and, when the water gets lower, decay and produce disagreeable odors in the water. Kelp (brown algae) is used to a considerable extent as fodder for cattle and as fertilizer

[1] The empty wall of the first cell soon disintegrates or breaks down and disappears.

for the land. On the Pacific coast these brown algae are collected in vast quantities and used for the extraction of iodine. Gelatine also is obtained from the red algae.

439. Fungi.—The fungi are the colorless plants. They have no chlorophyll. Fungi are common and some of them are tremendously important. The principal groups are bacteria, bracket fungi, earth stars, puffballs, yeasts, molds, mildews, rusts, smuts, and mushrooms. First let us learn something about bacteria.

Bacteria.—These are microscopic fungi which reproduce by fission. It is strange how many different views people have about bacteria. Some persons seem to think that bacteria are the common enemy of man; others believe that they cause all of our diseases; many more believe that we should be far better off without bacteria at all. As a matter of fact, none of these views is entirely correct.

In size, bacteria are the smallest of all living things. Some of them are so small that it would take 125,000 of them placed side by side to make a line an inch long. Since they do not possess chlorophyll, they cannot make their own food as the green plants can, and therefore are either parasitic or saprophytic. A **parasite** is an organism which spends its life on or within the body of some other living organism. An example is the tuberculosis bacterium. A **saprophyte** is any organism that lives within or on any non-living plant or animal. The decaying of meat is caused by these plants.

440. Bacteria are of three kinds: cocci (spherically-shaped), bacilli (rod-shaped), and spirilla (corkscrew-shaped). Many of them are able to move with a wiggling motion. Anyone who has done much work with the compound microscope has seen many bacteria.

Many forms of bacteria have no economic importance to man, since they are neither beneficial nor injurious. Many others are of value to us. The bacteria of decay cause the decomposition of organic fertilizer in the soil and thus set free quantities of chemicals to be used as food by our field crops. Do you

remember that the Indian taught the white man to raise corn by digging a shallow hole in the ground and putting in a dead fish along with a few kernels of corn, then covering them up with a thin layer of soil? The very success of raising that corn

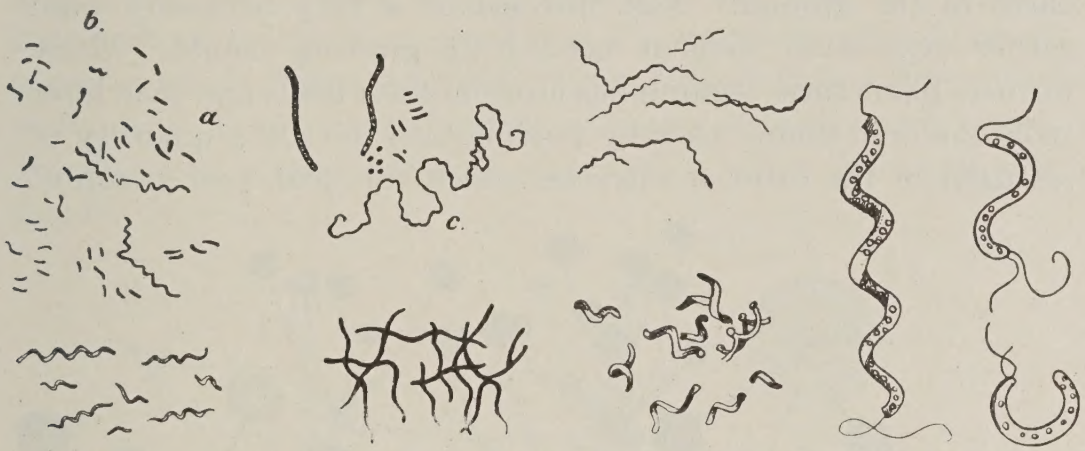


FIG. 211.—*A*. Different kinds of spiral-shaped bacteria, *spirilla*. (*After Flügge.*)

depended on the bacteria of decay, for otherwise the fish would not have become decomposed and the young corn plants would not have had enough food to grow and mature.

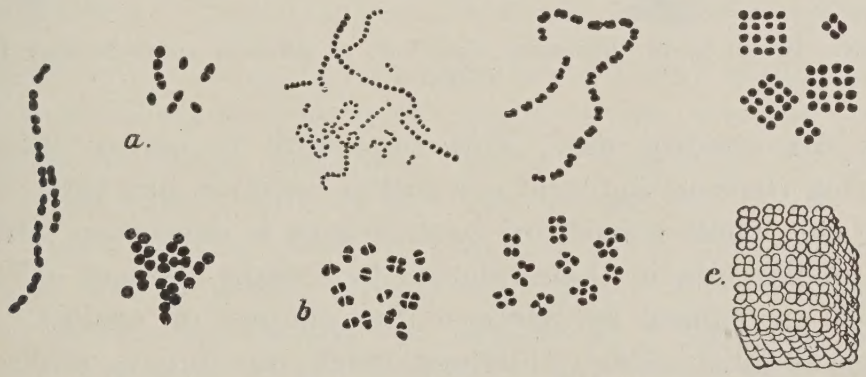


FIG. 212.—*B*. Various spherical-shaped bacteria, *cocci*. (*After Flügge.*)

441. Bacteria are also necessary in the preparation of sponges, the making of vinegar, the curing of tobacco and cheese to get the desired flavors, and in many other ways, such as putting nitrogen into the soil. Here the nitrogen-fixing bacteria play an important part. These bacteria are found in little nodules

on the roots of such leguminous (*leg-u'-min-us*) field crops as clover, alfalfa, peas, and beans. These bacteria extract free nitrogen from the air. Some of this nitrogen is used as food by the bacteria, but much is stored in tiny nodules on the roots, there in the ground. Now nitrogen is a very necessary (and rather expensive) element needed by growing plants. Many farmers plant these leguminous crops in their fields and then later plow the crop under, thereby putting into the soil a quantity of nitrogen in the form of nitrates, which the next year's crop of

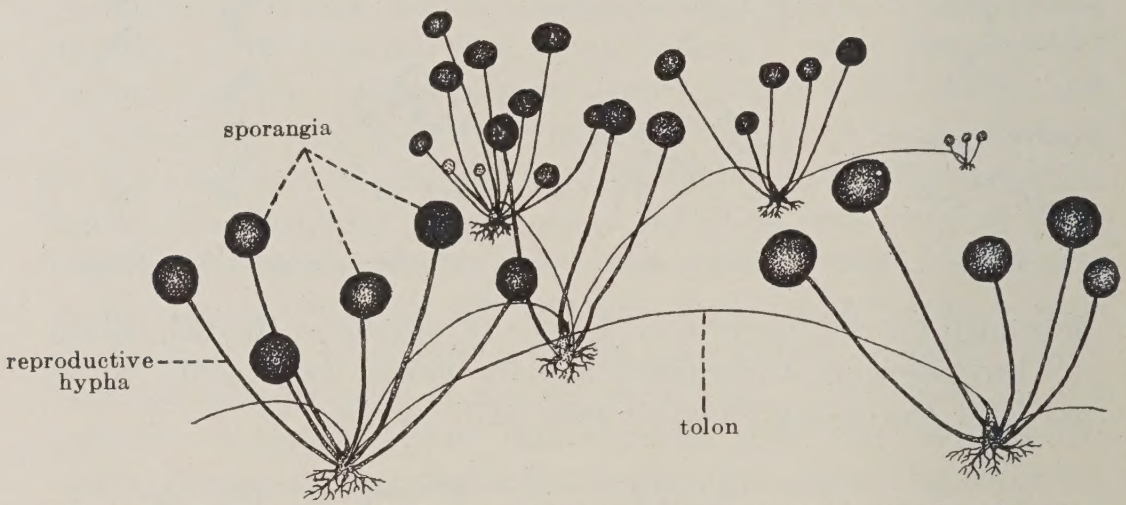


FIG. 213.—Bread mold, *Rhizopus nigricans*, a common spore-bearing fungus. (*Mottier.*)

plants can readily use. This procedure is known as green manuring (*man-ur'ing*) and is a rather common practice.

But the whole science of bacteriology is concerned with the study of bacteria in their relation to certain diseases. Not all diseases are caused by bacteria (See chapter on *health*). Such diseases as tuberculosis, whooping cough, pneumonia, and scarlet fever are examples of bacterial diseases.

442. *Molds.*—Mold plants grow on a variety of dead organic matter, especially if it is moist. They do not need sunlight. One of the most familiar examples of the mold plants is the common bread mold, often seen as a fuzzy growth of interwoven filaments, spreading about over the surface of stale bread. From this mass, known as the **mycelium,** many tiny root-like **rhizoids**

extend downward into the bread and thus secure nourishment. Tall, slender stalks known as **hyphae** rise upward above the mass and form **sporangia,** or spore cases, in which the spores develop. These are microscopic, seed-like bodies and are the reproductive cells. Because of their minute (*min-ūt'*) size, they are readily blown about by the wind as soon as the spore case of the parent plant in which they are formed bursts open. Hence they often drift about in the air and get onto loaves of fairly fresh bread. Naturally, as a spore develops into a mold plant, the bread gets moldy.

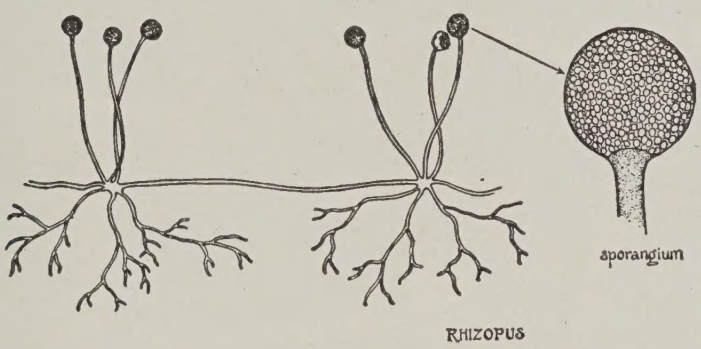


FIG. 214.—The bread mold produces an enormous number of spores in each of its sporangia because so few places are suitable for the development of new bread mold plants. (*Copyright by General Biological Supply House, Chicago.*)

Mildews.—A good example of these is the downy mildew which causes a considerable degree of damage every year by killing cucumbers, potatoes, and other plants. Likewise, the smuts and rusts take their toll from the field and garden.

443. *Yeasts.*—Yeast plants are important for their use in the making of bread and the fermenting of beer. The yeast plants produce carbon dioxide gas and alcohol by a digestive action on sugar, breaking it up chemically into these two simpler substances.[1]

When yeast, often from yeast cakes, is mixed with dough and kept warm for several hours, the yeast plants grow and give out

[1] Yeast plants are like the anaerobic bacteria in that they may get along better without external oxygen for respiration, getting this gas internally instead, as a by-product in the further disintegration of some of the carbon dioxide.

quantities of carbon dioxide gas which makes the bread "rise." Yeast plants are oval or elliptical in shape and are microscopic. They reproduce by a process called **budding.** First a tiny bud appears on any part of the parent plant. This bud grows and finally breaks away, forming a new, independent plant. See Fig. 246.

Mushrooms, sometimes called toadstools, are probably familiar to you. There is a large variety of them. They aid in the

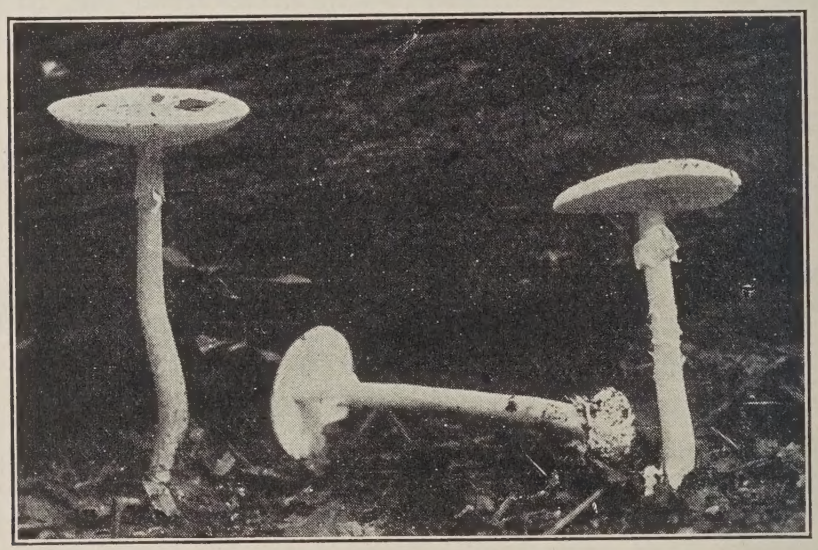


Fig. 215.—The deadly amanita, a very poisonous mushroom. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

decomposition of dead organic matter in the soil. A few species are edible but many more are poisonous. No attempt is made here to distinguish between the edible and the poisonous species, because general rules are not sufficient. No one should taste—*much less eat*—any species of wild mushroom until he thoroughly knows the edible species.

Other Forms of Fungi.—Bracket fungi are in many ways similar to mushrooms. Both reproduce by spores. Probably you have seen these strange growths on both living and dead trees in the woods.

Earth stars and puffballs are also fairly common. They grow on the ground. The cloud of "smoke" which is given out when

one steps on a puffball has given them their name. Earth stars also reproduce by spores. Earth stars are brown or gray colored and are somewhat star-shaped, having many conspicuous points.

Lichens are composed of algae and fungi living in close relationship, each depending upon the other. Any such mutual dependence between two different species of living things, whether plants or animals, is known as **symbiosis.**

FIG. 216.—The structure of lichens makes it possible for them to live in places which would be unfavorable for most other plants.

444. Mosses.—Who has not seen moss growing on rocks or tree trunks? Atkinson's[1] description of the mosses is so characteristic that it is given here: "The mosses are small, leafy-stemmed plants usually growing in dense tufts or mats on the ground, in swamps, moist woods, or other dry places, on rocks or on tree trunks."

A conspicuous part of the moss plant is the capsule which rises from the dense mass and contains the spores. The life history is

[1] Botany for Schools by George F. Atkinson. Henry Holt & Co.

quite unusual. These spores drift about or are blown about by the wind, as do nearly all spores, and give rise to new moss plants. These grow and, strangely enough, produce two kinds of plants: the male plants, which form the sperm cells; and the female plants, which form egg cells. When ripe, the sperm cells fertilize the egg cells and a new generation of plants is thus started sexually (i.e., from sperms and eggs). This generation, sometimes called the gametophytic (*gam-e-to-fit'ik*) generation, produces capsules which contain spores. So we have one generation formed from spores and the next one from sperms and eggs. They alternate, and this habit is known as **alternation of generations.**

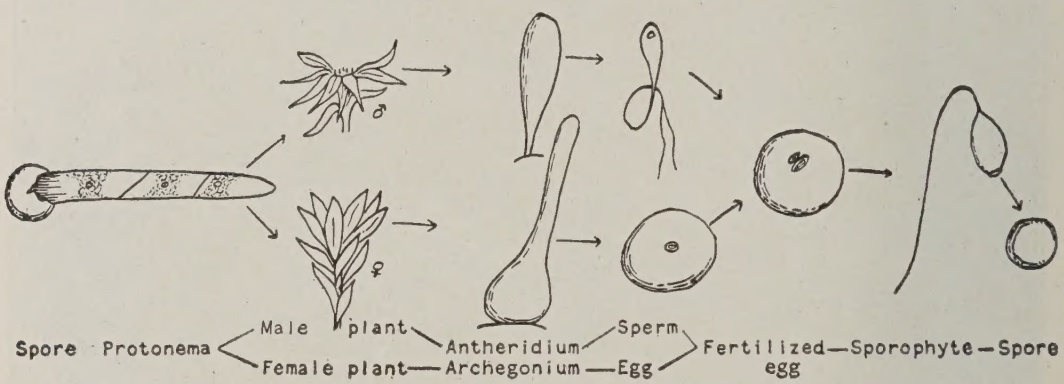


FIG. 217.—Diagram showing the life history of the moss plant. (*Atwood.*)

445. Ferns.—The beauty of ferns is known to everyone. Their extensive use as decorations is in itself evidence that they are appreciated. Somehow they suggest the quiet and peace of the moist woods, their natural home.

The life habits of the ferns are different from those of the mosses and yet very different from the flowering plants, for ferns do not have either flowers or seeds. They have a variety of leaf forms. These leaves are usually called **fronds.** Some of these are tall and quite straight and regular. Others, as in the maidenhair fern, are an intricate pattern of lacy network. Ferns love the deep woods. It is in the shade and the moisture here that they grow best, and here we should go if we would study them at home.

Having chlorophyll, ferns manufacture their own food from the soil water taken in by the roots and the carbon dioxide gas taken in by the fronds. Ferns have stems. They vary considerably, from the common small varieties up to the tall, tree-like species that grow in tropical countries. The latter often attain a height of forty feet. Many species have creeping underground stems bearing roots which aid them in getting food.

FIG. 218.—Ferns in the woods. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

446. Ferns, like the mosses, reproduce by **alternation of generations.** Surely you have seen the rows of brown-colored dots on the under side of the fronds, usually near the tips. These **sori** produce the spores, so you see that a single frond may form several thousands of spores. These spores germinate and form small, heart-shaped bodies called **prothallia** (*pro-thal'-e-ah*). If well developed, each prothallium has both male and female sex organs, thus producing sperm and egg cells. When ripe, the sperm cells move about and fertilize the egg cells. The fertilized egg cells are thus the beginning of a generation of fern plants, which will again form spores.

So you see that the fern plants themselves represent the asexual generation since they produce spores. The tiny heart-shaped

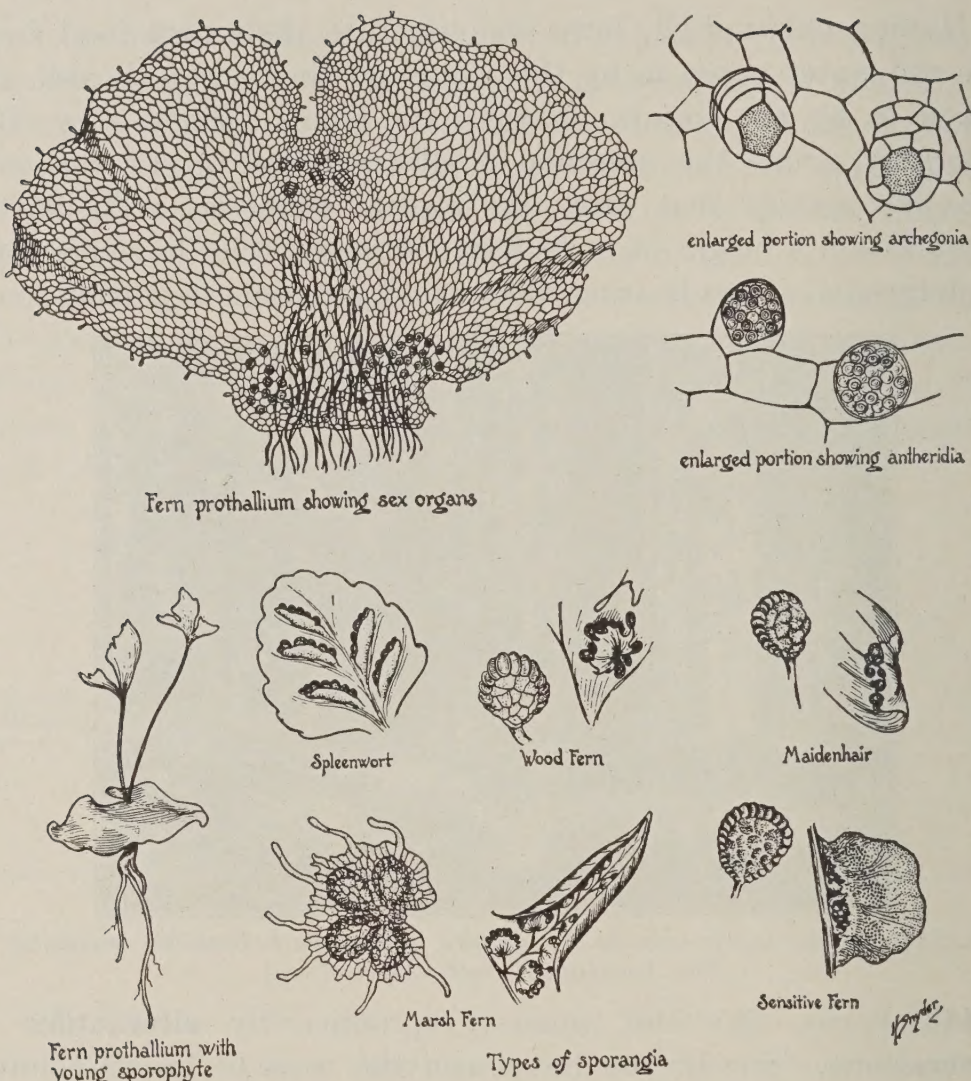


FIG. 219.—Antheridia develop among the root-like rhizoids, and archegonia grow near the notch of the prothallus. When moisture is present, sperm cells from the antheridia move toward the archegonia and unite with the egg cells contained within them. From the resulting fertilized eggs young plants appear and grow to maturity. Spores develop in the sori on the underside of the fronds, and from each spore a new prothallus may grow. Thus, in the life history of the fern, both a sexual generation (the prothallus) and an asexual generation (the frond-bearing plant) occur alternately. This "alternation of generations" is found among the ferns (Pteridophyta) and the mosses (Bryophyta). (*Copyright by General Biological Supply House, Chicago.*)

prothallia represent the sexual generation, since they form sperm and egg cells. Thus, the two generations alternate.

Relatives of the ferns are the horsetails or Equisetum (*ek-we-se'-tum*), the club mosses (which are not mosses at all), and the quillworts, which you have perhaps seen growing in the shallow waters of ponds.

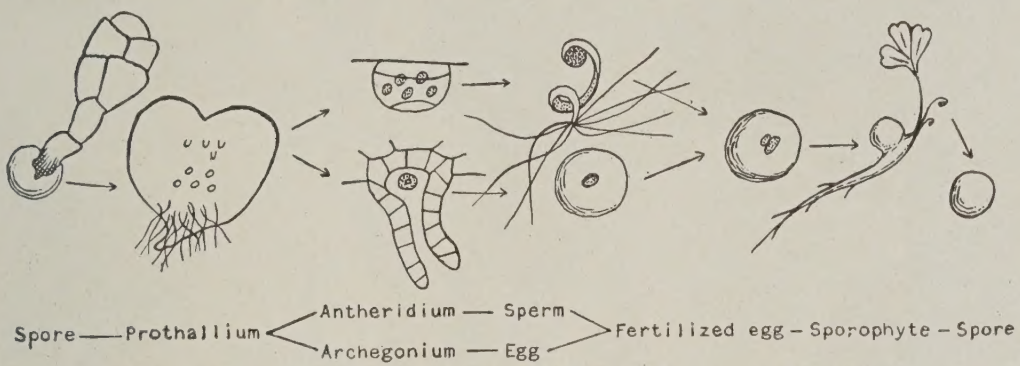


FIG. 220.—Life history of the fern. (*Corwin and Corwin.*)

447. A word should be said about the ferns of long ago, for they are important to us now although those species are mostly extinct. The fossil remains of plants formed in the different strata of rocks show us that these ancient forms were, for the most part, much larger than the ferns of today. At that time, so the geologists tell us, the climate was very different and at times much warmer than it is today. Also there was a much larger area of swamps, and the dense growth of ferns, horsetails, and club mosses grew to a large size. They lived and died, generation after generation, and their bodies were pressed down into the swamps by the weight of those that grew above them. This process continued for the hundreds of centuries that went to make up that Carboniferous age during which our coal was formed.

No one knows just how deep were those deposits of ferns and fern-like plants. But we do know that they contained a high percentage of carbon and that as they were pressed down more and more while the centuries passed, the oxygen of the air was shut off from them. Scientists estimate that these deposits

were between 900 and 1500 feet deep before being pressed into our coal layers which today are from 5 to 80 feet thick. And today we have several hundred thousand square miles of these areas from which we can get our coal. So you see that those

FIG. 221.—Orchids are among our most beautiful flowers. (*Robbins and Ramaley.*)

ferns of the long ago are more important to us now than the species which are living today.

448. The Flowering and Seed Plants.—Since flowers are discussed in another chapter, we shall here consider them only because they are members of the highest group of plants in the plant kingdom. It is said that even a bumblebee can appreciate a

flower; how much more so, then, should we appreciate the structure of this group of plants which produces them.

FIG. 222.—Unlike other flowering plants, the Indian Pipe lacks chlorophyll and cannot make its own food. (*Mottier.*)

The seed plants are of two kinds: the gymnosperms (*jim'-no-spurms*), like the pine trees whose seeds are not enclosed; and

the angiosperms (*an'-je-o-spurmz*), whose seeds are enclosed in a case, formed from the ovary of the flower.

Gymnosperms.—There are nearly three hundred different kinds of conifers—trees whose seeds are formed in cones. The pine is a good example. Here the male or sperm-producing cones are formed at the ends of the branches. They usually grow in clusters, and in the springtime when the ovules are ripe these cones give out showers of pollen which dust over the whole tree. The ovules are formed in the pistillate (*pis'-til-āt*) cones which, as the ovules ripen, turn upward and spread open. In this way they are much surer of being fertilized by the fine cloud of pollen which falls whenever a breeze blows or the branches are jarred. Aside from the presence of cones, these gymnosperms are always easily recognized by their clusters of slender, pointed leaves known as needles.

Angiosperms.—It is here that we find the true flowers, and flowers are the very highest development in the whole plant kingdom. We should remember that these angiosperms include that immense group of grasses which includes our common grains, as well as the common deciduous trees,[1] and the many varieties that we have always known as flowering plants.

It is now evident that among the many kinds of plants very few are able to move about. Any transfer in location of most plant species must be accomplished as a part of the reproductive process, that is, by the scattering of fruits, seeds, and spores. After plants become fixed in position by their root systems their home is wherever they may be, and they are not able to leave it, although it may be in a very unfavorable place.

Interesting Projects

1. Examine some plants which have been transplanted, and their environment somewhat changed. Do they appear to be in a healthy condition? Are they apparently having some difficulty in becoming adapted to the new environment? What are their chances of success in doing so?
2. Try to find some plant growing in an unfavorable environment. Where does this kind of plant usually grow? How do you think it might

[1] Deciduous trees are those that shed their leaves regularly each autumn.

have gotten to this place? Can you find any evidence to show that it is becoming adapted to the climate and new soil conditions?

Review

1. Why do seeds dispersed by such agents as wind and insects have a better chance to find suitable places?
2. What conditions of moisture and soil must one bear in mind when transplanting any plant, if it is to become adapted to the new environment?
3. Why do trees in a dense forest growth shoot upward and become very tall in proportion to their thickness? What conditions are they becoming adapted to, as they reach upward into the sunlight?
4. Why do the roots of certain desert plants extend downward for a considerable distance into the ground?

Define

algae **moss** **thallus**
fungi **locomotion**

CHAPTER XXVI

MOST ANIMALS, BEING ABLE TO MOVE ABOUT, CAN CHANGE THEIR ENVIRONMENT

449. We commonly associate motion with animals, and it is sometimes assumed that this ability is characteristic of all animal forms. There are many species of animals, however,

FIG. 223.—A colony of simple sponges. × ½. (*Reese.*)

which do not possess the power of locomotion at all, and others become fixed in position during the adult period of their lives. One has but to recall the barnacles so often seen attached to rocks and piers at the sea shore to realize the truth of this statement. Other animals such as sponges, oysters, sea anemones, and many hydroids are free-swimming when young, but later becoming attached, are no longer able to move about.

The history of organic development, as shown by the fossil record, indicates that the earliest plants and animals lived in the ocean. This same record shows, too, the beginnings of locomotion among the many-celled animals. Slow, awkward, with the body supported almost entirely by the buoyancy of the water, no highly developed appendages were necessary. Much later, the primitive fishes of the shark type lifted their bodies off the floor

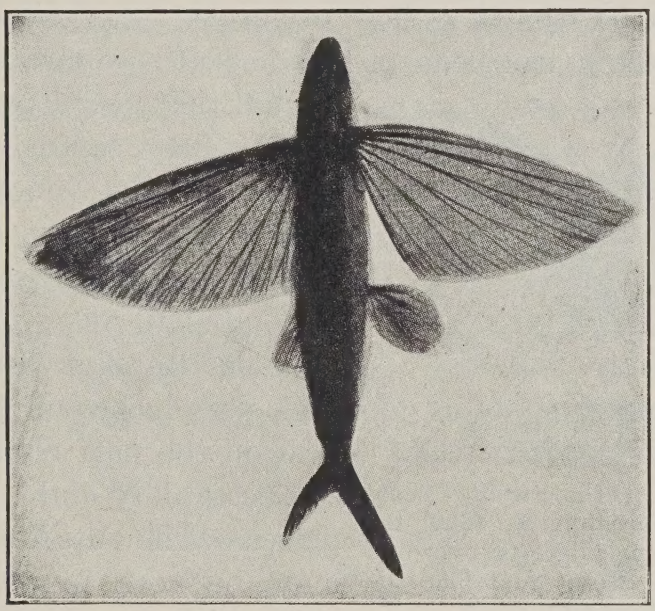


FIG. 224.—By attaining sufficient speed, flying fishes can glide short distances through the air. They cannot fly. (*Holmes.*)

of the ocean by using their fins and by attaining sufficient speed. Lacking the swim bladder of modern fishes, and therefore having no buoyancy, these pioneers in locomotion had to move constantly, like the modern airplane, in order to stay up. Some of the modern relatives of this primitive type of fish, such as the skate and ray, have returned to the indolent ways of their earliest ancestors, and now remain close to the bottom.

450. From the fin type of appendage found among the fishes, the inefficient appendages of the simpler amphibians were slowly derived. Becoming more and more efficient in the reptile group, we have seen how wonderfully the appendages, especially the

anterior appendages, have become adapted in the birds, and in the highest of the mammals, man.

All the higher forms of animal life possess a well developed nervous system, enabling them to keep in contact with their surroundings, and to learn a greater variety of new activities. But merely to be **aware** of the approach of an enemy, or the nearness of food would not of itself guarantee safety or a supply of food. The consciousness of the food or the enemy, however, when coupled with the ability **to secure** that food or **to escape** from the enemy has been of life-or-death importance to every animal that ever lived.

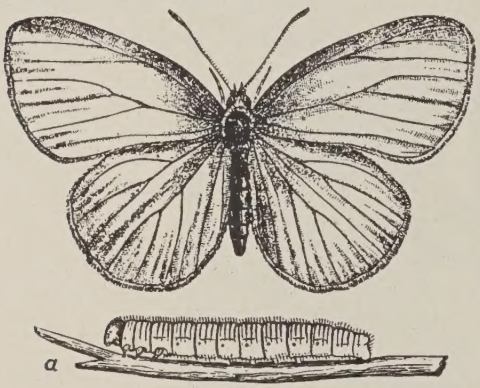


FIG. 225.—In the twenty years after its introduction, in 1860, the cabbage butterfly migrated over half of the United States and Canada. (*Corwin and Corwin.*)

451. The saying that "one supply makes another want" applies here to the development of animal species, for along with the ability of the predatory animals to find and to catch their prey has come the increasing skill on the part of the hunted to escape rapidly and to find hiding places. The outgrowth of all this may be seen in such ways as the building of nests, and the digging of burrows in the ground, the better to escape from enemies and from the cold of winters. Thus the ability to move about has resulted in the migration of birds and of many fishes, and the roaming of many other wild animals in the attempt to change their environment.

452. Our most complete record of the movements and the migrations of animals resulting from various causes is that of man, since we have abundant archaeological evidence in the ancient script and hieroglyphics coming down from prehistoric times. Let us briefly examine some of the causes of these movements. Uncertainty of a dependable food supply led man to till the fields and to domesticate certain animals. He became less of a nomad or wanderer, but as the food supply for his herds

fluctuated he was forced to pasture them farther away and to keep in frequent search of new grazing fields. Later, well-ordered communities were developed and, as these became overcrowded, the frontiers were pushed back, and the uncivilized, or in other words the less well adapted, were crowded out or assimilated with the stronger group. The replacing of the American Indian by the white man is an example of this. Desire for freedom from social or religious bondage such as the conflict which drove the Pilgrims from England; hunger, greed—all have played their part. Today political greed and an actual need for expanding room are having a marked influence on the peace of the East.

The Eskimos spend the winters near the coast where they can be sure of food from the seals they kill; in summer they migrate inland to hunt the musk ox and the reindeer. The game, too, migrate seasonally into new and better feeding grounds. Thus competition with the environment and with other organisms, combined with the ability to move about, has provided the animals with a greater development than is found among the plants.

Interesting Projects

1. From the books in your library find out what particular groups of animals move from one locality to another at certain times of the year. Why do they do this? Do they migrate to and from these same places periodically every year?
2. Learn about the migration of the salmon up the Columbia river every year. Are there any species of fishes in your state which have regular migratory habits? Why do fishes migrate?
3. Look up the life history of the fresh water eels. Find out where they lay their eggs, and whether they return to their natural habitats after the breeding season.

Review

1. Do such animals as clams and oysters need protection from their enemies? If so, how do they protect themselves?
2. Are those species of animals which move about from place to place, subjected to more dangers than species which are attached?

3. What conditions may cause animals to move into a different environment?
4. Why have roving animals such as foxes a better chance to become located in a favorable environment?

Define

barnacle **hydroid** **sea anemone**
environment

CHAPTER XXVII

PLANTS AND ANIMALS DEPEND UPON EACH OTHER AS WELL AS UPON THEIR ENVIRONMENT

453. Our interest in biology was probably stimulated in the first place by the fact that wherever we go, we see at every hand a vast array of plants and animals. Let us be more specific. First there are the plants and flowers that we see in our homes,

FIG. 226.—The gray squirrel, unlike the green plant, can not make its own food. It, therefore, needs sense organs to aid in locating food, and organs of locomotion to obtain it. (*Corwin and Corwin.*)

and the animals which we have as pets, while on our walls the paper often presents varied designs of flowers and leaf patterns of wide assortment. Then come our flower and vegetable gardens; also our fruit and field crops, so important in helping

to make up the great variety of organic products that constitute our foods. Perhaps we have never thought just how much the plants and animals out-of-doors mean to us, but what would our long summer vacations be like without them? These animal and plant forms are all included in biology—these and many more.

But have you ever asked yourself, "Are these living things all related to each other and are all animals really dependent upon plants?" If so, your answer should have been "yes," for we,

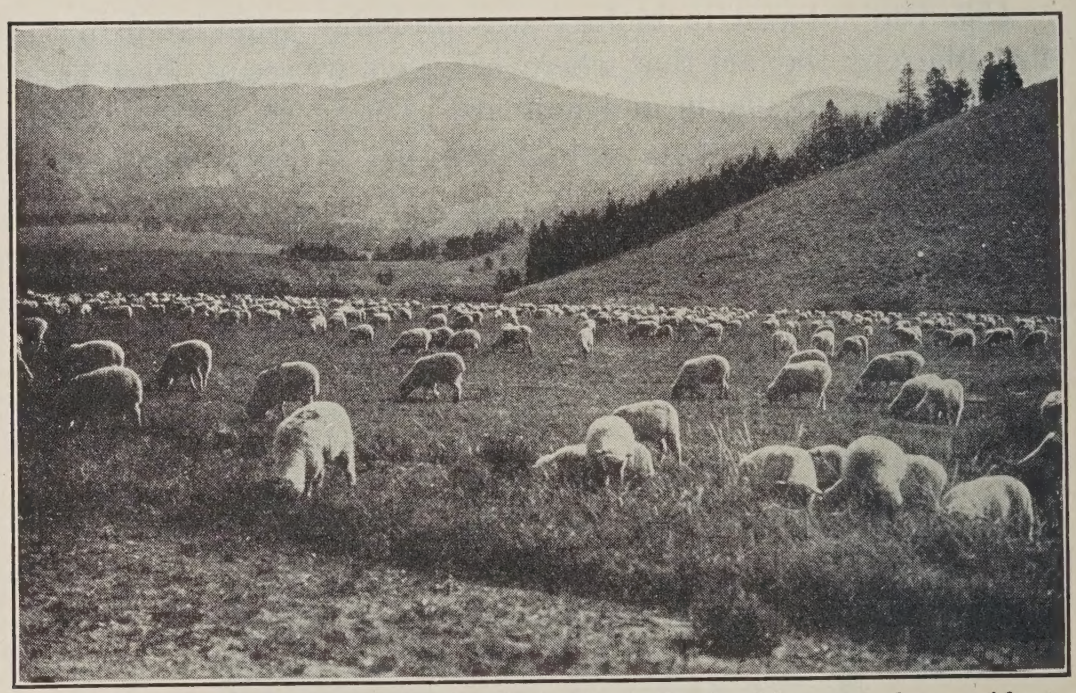


FIG. 227.—The dependence of animals on plants for food is everywhere evident. (*Photo by S. B. Locke.*)

like all the other animals are dependent for our very lives on the plants. And, likewise, the plants are dependent for existence upon the animal kingdom. Let us see how this dependence is possible.

454. The Food of Animals.—All the grazing animals such as sheep, cattle, deer, buffaloes, and reindeer depend directly and entirely upon the plant kingdom for their food. Without plants they could live only a very few days. Then there is the large group of carnivorous animals such as the foxes, wolves, bats,

lions, and many others, which feed on flesh. They feed on other animals which in turn feed on others, whose food is plants. The fox, feeding on rabbits and mice which feed on plants, is an example of the dependence of animals on plants. Thus we can safely say that without plants for food, all animals would perish.

455. The Food of Plants.—Why does the farmer use the animal wastes from the barn and stable to fertilize those fields where he hopes to raise good crops? Because those substances are the food of plants. Did you know that the waste from slaughter houses

FIG. 228.—Fertilizing the land before planting. (*Canadian Government Photo.*)

and from the great canning factories where salmon and other fish are canned, are used in making fertilizer for the land? Again, it is because the animal bodies themselves as well as their wastes are the food for all sorts of plants. Did not the Indian who planted a dead fish along with the corn kernels in the hill of corn demonstrate that plants feed on animals?

456. The Oxygen Supply for Living Things.—Since every organism requires oxygen in order to oxidize its food, this element must be taken in regularly throughout its entire lifetime. But unless large quantities of this gas were constantly being turned back into the air and the water, life could not continue either in the waters or on land.

457. The whole world is indebted to the green plants for its oxygen supply. They set free enough of it to supply their own

needs and also those of the fungi[1] and the animals as well. Since green plants of all kinds carry on this work of photosynthesis you can readily see that during every hour of daylight large quantities of this gas are liberated. This supply is constantly being drawn upon by animals and all other living things.

458. Animals and Carbon Dioxide Gas.—What is carbon dioxide gas? The chemist tells us that it is composed by volume of one part of carbon to two parts of oxygen. It is the gas contained in the air which we exhale. Every other organism exhales carbon dioxide gas. It does not support combustion nor does it support animal life. Every animal is giving it out continuously into the air (or into the water if the animal is aquatic). The carbon dioxide must, therefore, be taken from the air and more oxygen set free for the animals to breathe. A fire is immediately put out by carbon dioxide because this gas does not permit oxidation (combustion) to take place.

459. Plants and Carbon Dioxide Gas.—But what can the plants do about purifying the air? There is an old saying that "What is one man's meat is another's poison." This can well be applied to carbon dioxide gas, for while it is the animal's "poison" in the sense that it cannot oxidize their foods, we must remember that it is the green plant's "meat." It is one of the raw materials necessary for making their food. Every green plant grows by making glucose or grape sugar[2] from the water that is taken in through the roots into the stem and leaves, and the carbon dioxide that is taken in from the air through the stomata. Hence the plant must have carbon dioxide gas. Some carbon dioxide gets into the air from the smoke of fires—through the chimneys and smoke stacks of a million factories and houses;

[1] Since fungi have no chlorophyll, they can neither produce grape sugar nor liberate oxygen. Anaerobic bacteria are discussed elsewhere in this book.

[2] Some of this grape sugar is changed into starch by losing, through evaporation, one molecule of water, and is thus stored in the plant for later use. But much of this sugar is used directly for growth and repair, by the plant itself.

some comes from the decay of all sorts of perishable things, and large quantities come from the respiration of animals.

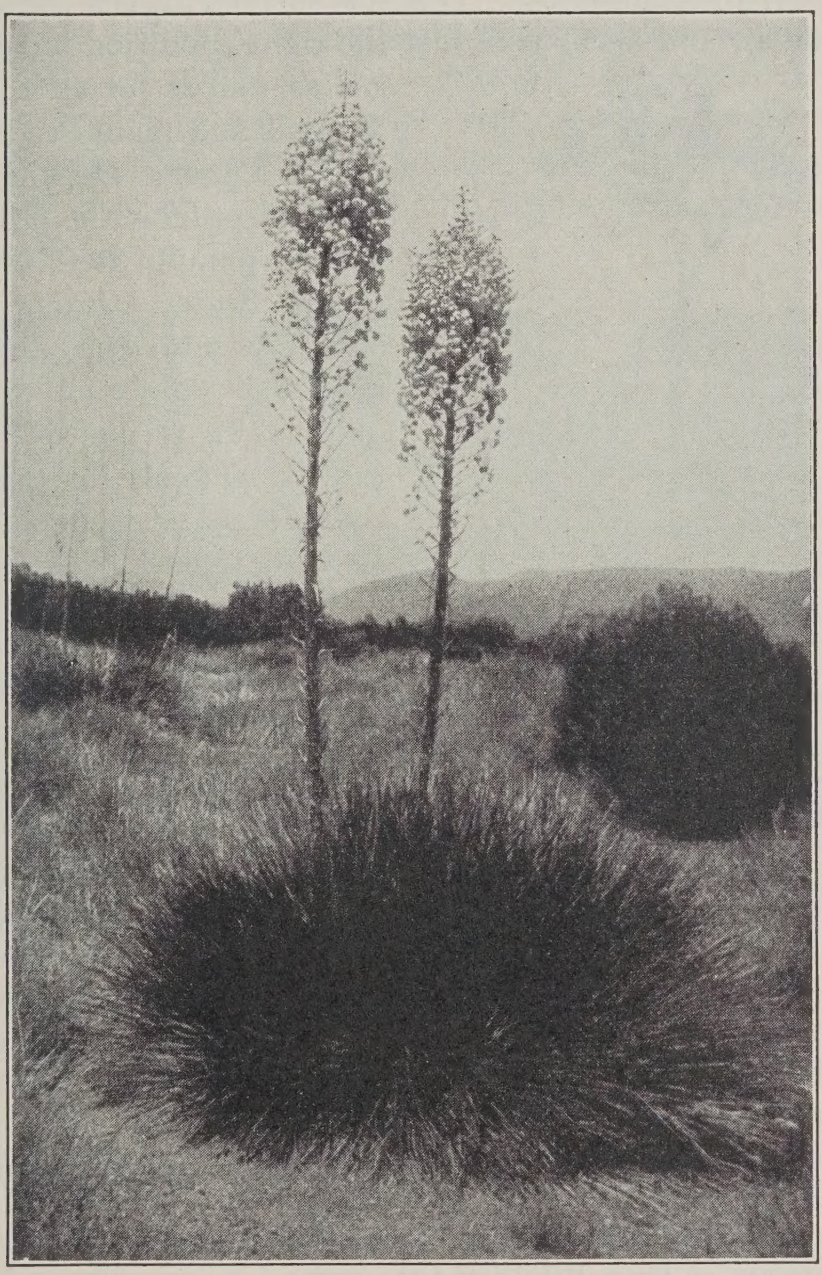


FIG. 229.—The Yucca plant has a very unusual method of pollination. (*Corwin and Corwin.*)

460. You see, in order to get the necessary amount of carbon and hydrogen to make the grape sugar which is its food, the plant

has to take in three times as much oxygen as can be used,[1] and so the rest of it has to be given off into the air as a by-product that the plant cannot use. It is this surplus oxygen that replenishes the air and keeps it in just the right condition for you and me as well as for all the other animals and plants to breathe.

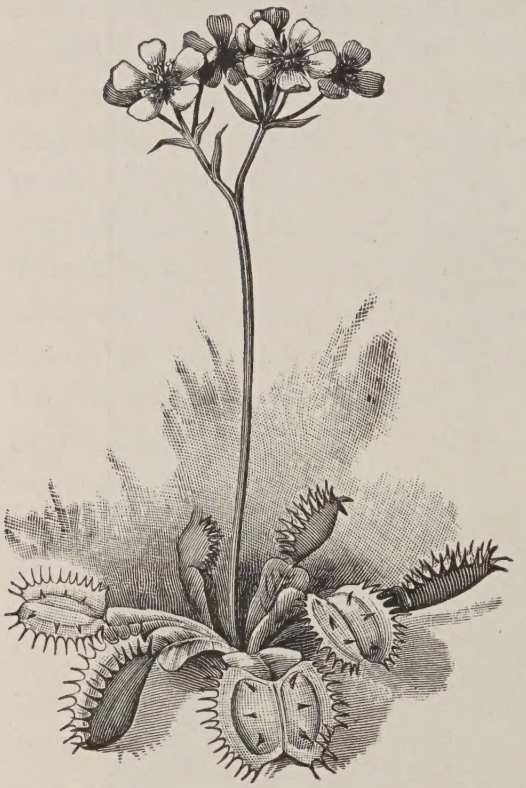


FIG. 230.—Venus fly trap, a plant that captures insects to increase its supply of nitrogenous food. (*Atwood and Heiss.*)

461. Other Dependencies. Transpiration is the process by which plants give off their excess water through their stomata into the air. This process is vitally important to plants. It is likewise important to animals for the water that it supplies them indirectly. It also makes possible the moisture and coolness of the woods.

Then, too, many plants are dependent on animals for dispersing their seeds. Have you noticed how many country fences are lined by wild cherry bushes which have sprung up from the indigestible seeds left there by the birds? Or the many beech, oak, and other trees, whose seeds were "planted" when they were dropped by some bird or squirrel? You have only to be reminded of the great dependence of plants on insects and on some of the birds in getting their blossoms cross-pollinated.

[1] It is believed that three or more chemical changes take place during photosynthesis. $CO_2 + H_2O = H_2CO_3$ (carbonic acid). This is probably changed into formaldehyde and oxygen by the energy of light acting upon the chlorophyll. $H_2CO_3 = H_2CO + O_2$. This formaldehyde, in turn is converted into glucose, being aided, no doubt, by further light energy. $6H_2CO = C_6H_{12}O_6$.

462. Think of the yucca, that semi-tropical lily, whose pollen is produced lower down on the plant than are the stigmas. Obviously the pollen cannot fall upward. The large white blossoms are pollinated almost exclusively by the pronuba moth, which places the pollen on the stigma with her eggs. Thus she insures a development of seeds and fruit on which her larvae can feed. As not all of the seeds are destroyed, the yucca benefits by this method, too. It is said that without the pronuba moth this lily cannot produce any seeds.

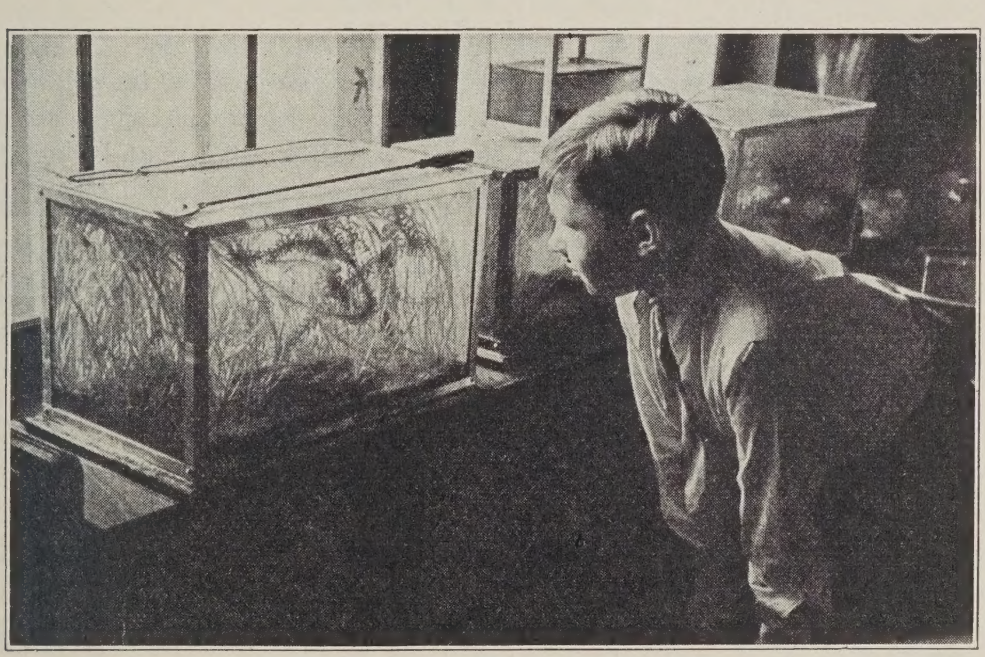


FIG. 231.—The balanced aquarium may be thought of as a small pond brought indoors. (*Copyright by General Biological Supply House, Chicago.*)

463. Or recall the Venus, fly-trap, the pitcher plant, and the sundew, that live in moist places where the soil is acid and contains little nitrogen. One of their main sources of this necessary element is the bodies of the animals which they "catch."

On the other hand, think of all the thousands of furred and feathered animals whose home is the forest. Here they get protection, shelter, and food.

464. Conclusion.—The world of living things is made up, as you know, of two great kingdoms—the plant kingdom and the

animal kingdom. Neither one of these is complete without the other. As in the balanced aquarium, where the water is never changed, if the plants die the animals will die also. And the reverse is equally true. Each half depends upon the other half.

Why not carry this idea further in your own observations from day to day? You have no idea how many other dependencies you will find—in how many different ways each kingdom depends upon the other one.

Interesting Projects

1. Build or buy an aquarium jar or tank and stock it with goldfishes. Notice how often the fishes come to the surface for oxygen whenever the water needs changing. Put in a supply of aquatic plants and place the aquarium where it will get sunlight. What changes do you observe in the behavior of the fishes?
2. Transplant some bush or plant growing in dark, rich soil to some spot having light, sandy soil with little organic food in it. Does the plant flourish and grow well? Try working some animal fertilizer into the soil around the roots, watering the plant whenever necessary as before. Does the plant respond to this treatment by showing renewed growth, or has it no effect?

Review

1. In what ways do plants depend upon animals?
2. How should we be affected if all plants died?
3. In what ways do the plant and animal kingdoms depend upon each other?
4. What dependence does the yucca lily well illustrate?

Define

oxidation **seed dispersal** **transpiration**

UNIT VI

WE ARE LIVING IN AN EVER-CHANGING ENVIRONMENT

CHAPTER XXVIII

THE CLIMATE OF ANY PART OF THE WORLD IS VERY SLOWLY BUT CONTINUALLY CHANGING

465. Geologists study the formations of rocks, and attempt to explain the changes that have occurred since the time when the earth was a great mass of molten rock. The length of time required for these changes must be measured in terms of millions of years—almost inconceivable to the human mind which is accustomed to measure time in terms of years or, at the most, hundreds of years. Therefore the climate of any one locality changes so slowly that the difference would not be perceptible within the lifetime of a person. In fact, the longest complete and accurate records of our weather bureaus fail to show an appreciable change in periods as long as fifty years.

466. Geologists remind us, however, of the coal deposits in Greenland and Russia. It is known that coal can be formed only in warm, moist regions where vegetation can grow luxuriantly. The only possible conclusion, therefore, is that the climate of the regions now so cold for a greater part of the year was at some earlier period similar to the present tropical climate.

467. In contrast to this condition, geologists can show conclusive evidence that at several remote periods great ice sheets, many feet thick, extended from the north well into the regions now occupied by the United States. These periods may have influenced the development of the migratory habits of birds and the extinction of the enormous prehistoric reptiles. Certainly

they must have influenced organic life profoundly, and doubtless brought about the extinction of many species of organisms.

468. It is fortunate for organic life that these climatic changes occur very slowly because organisms become adjusted to great

FIG. 232.—These caribou have become adapted for living on moss and the scanty vegetation found in the far north, now so cold, where few animals so large could survive. (*From Ingersoll "The Life of Animals."*)

change only with difficulty. Where new structures are necessary, as when the feathers of the first species of birds developed from the scales of the flying reptiles, a long time is required.

469. Just as this process of change in climate is continuous, so must the change in adaptations and the development of new modifications in structure be carried on constantly. Those

species of plants or animals which, for one reason or another, are inflexible, and not capable of making changes rapidly enough to accompany the changes in climate, become extinct. One of the most remarkable characteristics of protoplasm as it is

FIG. 233.—Young gorilla at left; chimpanzee at right. The chimpanzee and the gorilla are primates which are adapted to live in the warmer climates. (*Zoological Gardens of Philadelphia.*)

represented in the many species of plants and animals, both living and extinct, is the great diversity of adaptations which have been developed, and the changes in structure to conform to new conditions. Biology is largely concerned with an understanding of these modifications.

Interesting Projects

1. From a textbook on geology, learn why the older layers of rocks, although usually located deeper than more recent formations, may sometimes be nearer the surface.
2. What evidence shows that part of the United States has been covered by great ice sheets at different periods in the past?

Review

1. Why is the change of climate in any one locality hardly noticeable to us?
2. What is the evidence that Greenland, northern Canada, and Russia once had warm climates?
3. How does a change of climate influence adaptations of both plants and animals?

Define

adaptation **modification** **prehistoric life**
geologist

CHAPTER XXIX

THE SURFACE OF THE EARTH CHANGES SLOWLY BUT CONSTANTLY

470. If it were possible for you to occupy, temporarily, any part of the earth's surface at any time you chose—one—two—possibly four million years ago, you would be impressed not only by the differences in organic life and the changes in climate, but also by the differences in the location and extent of the land masses. It is believed that as the molten earth cooled, it shriveled, much as an apple shrivels as it gets old. This shriveling process resulted in pushing up land masses as continents. In the depressions, the newly formed water vapor condensed to form oceans, seas and lakes. The influence of the sun caused air currents, as the heated air rose and the cooler air rushed in to take its place. These air currents resulted in the formation of winds. The water which evaporated from the surfaces of the bodies of water condensed as rain or snow, according to the temperature, and formed brooks, rivers and glaciers. In time these weathering processes wore away the land masses, breaking rocks into gravel or sand and carrying much of the sand with its organic particles into the sea.

471. Great accumulations of material on one portion of the earth may push up land at other places. Thus the process continues indefinitely and if a sufficiently long time is involved no mountain, valley, sea or continent is permanent. We must keep in mind, however, that very long periods of time are required for these changes.

472. Geologists have produced abundant evidence of land bridges, existing long ago, which connected Siberia in Asia with Alaska, and the British Isles with the mainland of Europe. The

eastern coast line of North America was, at one time, undoubtedly at least one hundred miles farther east. The peninsulars which connected the large land masses, such as the eastern and western hemispheres at Alaska, permitted land animals to migrate, and by competition with new types and new conditions, to progress—new species and sometimes new genera resulting from the process.

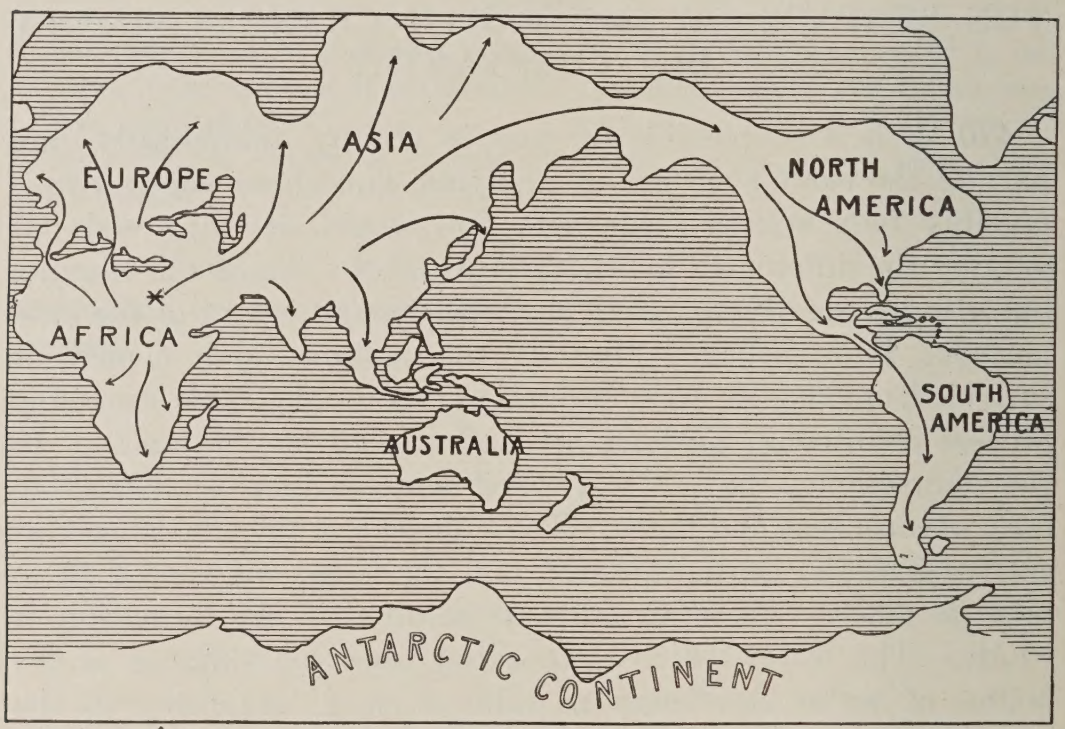


FIG. 234.—A map showing land bridges which existed in prehistoric times between the continents. (*American Museum of Natural History.*)

473. The great depth of water between Australia and Asia indicates that the island continent was connected with the mainland of Asia either a *very* long time ago, or not at all. This is substantiated by the fact that Australian plants and animals are simpler in structure—more like the earlier plants and animals of other parts of the world. They have not been changed by competition with so many other species of organisms, because they could not migrate where others were, nor could other forms surmount the barrier of many miles of ocean and come to them.

These continuous changes among both the organic and the inorganic earth structures lead us to a general statement about nature that becomes evident at this point—a statement that seems

FIG. 235.—The spiny ant-eater is found in Australia. Although it is a mammal, it lays eggs. A model of its egg is shown at the right. (*American Museum of Natural History.*)

like a paradox until you have thought about it for a while. It is that; "there is nothing constant in nature but change."

Interesting Projects

1. Make drawings in your note book to show how the different continents have changed in shape and size during the different geologic ages. (Look in the "historical geology" section of a textbook on geology.)
2. Make sketches of some of the plants and animals living at the different geologic periods, but which are no longer in existence.

Review

1. Explain the method by which the surface of the land has been worn away.
2. How has the existence of land bridges, in the past, assisted in the distribution of plants and animals?
3. In what ways has competition among plants and animals affected them?
4. Why are many of the plants and animals found in Australia different from those in other parts of the world?

Define

earth depression **land mass** **molten earth**
land bridge

CHAPTER XXX

ORGANISMS MUST BECOME MODIFIED IN ORDER TO BECOME ADJUSTED TO NEW CONDITIONS

474. No organism in the world finds conditions perfectly suited to it. On the contrary, each plant or animal must become

FIG. 236.—The mud puppy or water dog has certain characteristics of the water-inhabiting animals, and other characteristics of the land-inhabiting types. (*Corwin and Corwin.*)

adjusted to conditions as they are found, unless such adaptations are provided by heredity. Just as the baby, by laborious muscular and nervous adjustment learns to walk, or discovers by bumping its head that floors are hard, or by burned fingers becomes aware that fires are a source of danger, so do all its organic relatives face a competitive world that requires a maxi-

mum of adjustment if survival for any length of time is to be possible. From the simplest organism to the most complex we find this compromise with nature's forces.

475. We have learned that certain of the one-celled animals produce a firm membranous wall, or cyst, around themselves

FIG. 237.—Adapted for hanging in a suspended position underneath branches, the sloth avoids competition with animals that walk on the upper sides of the branches. This lack of competition has caused its sense organs to deteriorate. It no longer has keen senses of hearing, smelling or seeing. It feeds on leaves; moves only seldom, and then very slowly. (*Zoölogical Gardens of Philadelphia.*)

when conditions are not suitable for active existence. We have seen how the higher invertebrates, such as the lobsters, are adapted for protection by a hard outer skeleton, and by the ability to produce new parts, such as claws, when the original ones are lost.

476. Usually these adaptations, to be successful, require a modification or change in structure. When fish-like forms moved onto the land, the appendages were poorly suited for getting about. Therefore we note a gradual change from the inefficient appendages of animals like the mud puppy to the more effective

appendages of the reptiles, and finally to the highly adaptable arms and legs of the most complex mammals. We know, in the case of certain plants, that leaves are modified into thorns to provide an adaptation for protection; that leaves are modified into tendrils to permit a climbing plant to lift its leaves up into the sunlight; and how more leaves are provided than are actually needed, because of the almost certain ravages of insects. When we studied mammals we learned what great modifications in structure became necessary when the whale and the bat abandoned so completely the methods of locomotion of their mammalian relatives and one took to the water, the other to the air.

477. We organisms are but bundles of adaptations. As time has passed, the protoplasm of our bodies has been modified and re-modified countless times. And, as we have already noted, since conditions are always changing, so must this process of modification continue to make possible new adaptations, with the greatest success crowning the achievements of those plants and animals whose modifications permit them to become adjusted most completely to the conditions under which they live.

Interesting Projects

1. Make drawings of the paired appendages of the fish, amphibian, reptile, bird, and mammal. Write a description of the modifications that have taken place in each case.
2. Write a description of the modifications which take place in a person's behavior as a result of school work. How do these modifications assist in adjusting one to social conditions?

Review

1. How have plants and animals become adapted to extreme changes in temperature; to changes in the amount of light; to a shortage of food?
2. When the land-inhabiting animals developed from water-inhabiting animals, what changes became necessary in addition to the changes in the appendages?
3. What structures, present in both the whale and the bat, result in their being classified together?

Define

cyst **inefficient appendage** **survival**

UNIT VII

THE SUCCESS OF EVERY LIVING THING DEPENDS UPON THE EFFICIENCY OF ITS ADAPTATIONS

CHAPTER XXXI

THE GREATEST PROBLEM OF THE INDIVIDUAL IS SELF-PRESERVATION

478. Through the ages countless species of plants and animals have succumbed to competition with other organisms or with their environment. This eternal competition among living things impresses us early in our study of biology. Frequently intense, sometimes cruel, this struggle is stimulating, nevertheless, and assists materially in the development of adaptations.

FIG. 238.—Like other carnivorous animals, the bobcat has long, pointed canine teeth, and padded feet. (*Courtesy of Bates College.*)

479. The only method by which the many species of plants and animals can avoid extinction is to provide adaptations which will either prevent or lessen the encroachment of enemies or of adverse conditions. The diversity of adaptations is great, many of them being admirably suited for their function. Other modifications are hard to understand, and a few specializations in structure are carried so far that they become distinct handicaps *resulting* in extinction instead of *preventing* it. Certain of the prehistoric molluscs were in this latter class. Their shells became thicker and thicker until this protecting cover became so cumber-

some, or so laden with spines, that the animals were unable to move about to obtain sufficient food. Among mammals, so much was added to the antlers of the Irish stag through succeeding generations that their usefulness as protective devices became lost, and this species of animal passed out of existence. The great majority of protective adaptations, however, are distinctly advantageous, if combined with adequate reproductive ability, in maintaining the species.

FIG. 239.—The Irish stag with the over-developed antlers which brought about its extinction. In some individuals the distance between the tips of the antlers was eleven feet. (*American Museum of Natural History.*)

480. We have already noted the remarkable protective resemblance of most animals to their customary background. The almost universal presence of chlorophyll in plants renders the individual plant inconspicuous. We have learned how many lower animals are able to replace certain body parts lost in battles with their enemies. It is not difficult to make a long list of specialized protective devices such as horns, nails, hoofs, hair, scales, shells, spines, hard exoskeletons, sense organs, thorns, thickened epidermis, sticky or slimy secretions, regeneration and cysts. How many items can you add to this list? Which organism does each of the foregoing devices bring to your mind?

481. Although man has largely removed himself from the dangers of physical competition with enemies, he struggles in common with other organisms against his environment. There is also great need for adaptation in his social and business relationships. Physically, his clothes, his machines, his buildings with their heating and cooling devices are adaptations for protection and efficiency. And frequently financial and social

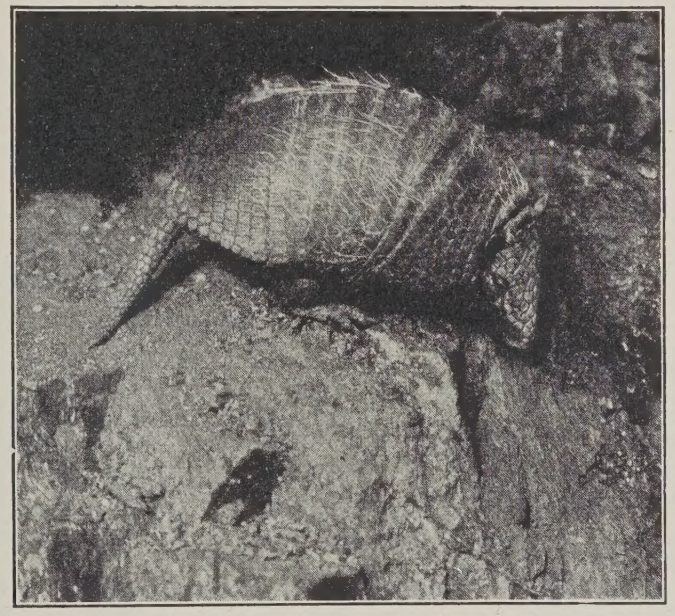


FIG. 240.—Its excellent adaptation for protection makes it unnecessary for the armadillo to be rapid in its movements, or to hide from its enemies. (*Reese.*)

success among his fellows depends upon his ability to become adapted to the needs of his clients, his patients, or his customers.

Interesting Projects

1. In a tabular form make a list of plants and animals with the adaptations of each for (*a*) protection, and (*b*) food-taking.
2. Make a list of man's adaptations for protection against (*a*) unfavorable weather, (*b*) insect enemies, (*c*) pathogenic bacteria, and (*d*) human enemies.

Review

1. How does competition among plants and animals assist in the development of new adaptations?

2. Give examples of adaptations which became handicaps and brought about extinction.
3. Make a list of organisms and forces of the environment against which man must compete.

Define

antlers **regeneration** **spines**
exoskeleton

CHAPTER XXXII

ADAPTATIONS FOR NUTRITION AND PROTECTION MUST MEET DEFINITE NEEDS

482. Protoplasm becomes modified in many ways due to its response to certain stimuli. This property of sensitiveness, combined with the needs of the organism, such as the need for food

FIG. 241.—The beaver has become adapted for protection by building its house in ponds, usually of its own making. The floor of a beaver house is always above the level of the water. (*American Museum of Natural History.*)

and the need for protection, often direct the modifications along specialized and definite lines.

The response of protoplasm to a stimulus, in organisms not having a nervous system, is known as a "tropism" (*tro'pizm*), and we find such plants and animals usually responding in a fixed way to touch, temperature, chemical substances, electricity, light, moisture and gravity. When the response is toward the

stimulus, it is said to be **positive;** when away from the stimulus, it is **negative.** Therefore, when stems grow toward the light,

FIG. 242.—The begonia at the left received light from all directions. The other one received light only from the right. This turning toward the light is known as positive phototropism. (*Atwood and Heiss.*)

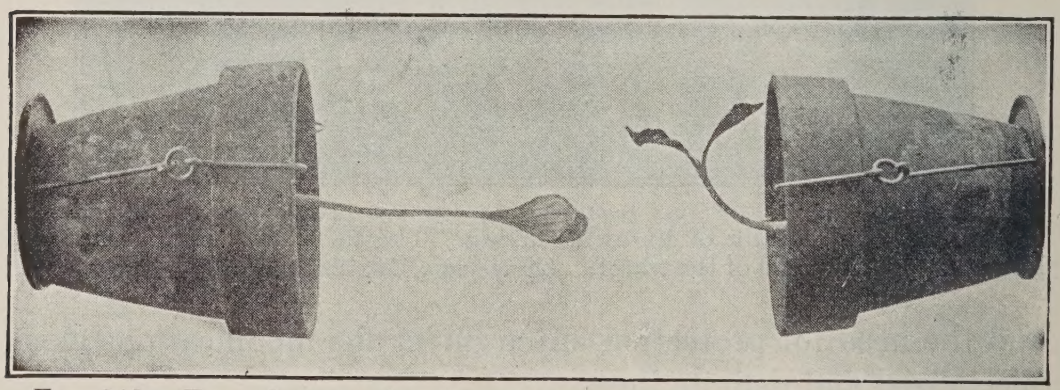


FIG. 243.—Two photographs of a growing squash seedling showing negative geotropism. When the flower pot at the left was rotated, the plant grew straight out. When the motion was stopped the seedling grew upward, that is, away from the earth. (*Atwood and Heiss.*)

the act is known as positive phototropism. But when you saw the paramecia move away from the bright light of the microscope

FIG. 244.—A geranium cutting with the soil removed from the roots, showing their direction of growth. The dry soil is at the left and the moist soil at the right. The direction of growth of the roots shows positive hydrotropism. (*Atwood and Heiss.*)

FIG. 245.—The star-nosed mole. The nose and front feet of this animal are well adapted for burrowing. (*Ontario Highway Department.*)

field, they were negatively phototropic.[1] When you were studying plants, the prefix *photo* was used as a part of the name of a very important process among green plants. Do you remember its meaning?

483. Among the simplest of organisms with more than one cell, a specialization in structure is necessary for each of the important functions. As plants and animals increase in size beyond the limits of the single cell from which each developed, the volume increases much faster than the area of the surface. The surface, therefore, soon becomes unable to absorb sufficient food and oxygen to supply all the cells. Specialized cells, tissues and organs become necessary, and these structures make possible a **division of labor** which becomes extremely complex among the higher forms.

Thus we find the forces of nature so acting in conjunction with the needs of the organism that structures assume modifications which will, as a rule, best fit them for the work they do.

Interesting Projects

1. Place any young seedling in a box and permit light to enter from only one small opening. What kind of tropism does the plant show?
2. Cautiously place a lighted match beneath a slide containing live protozoa, under a microscope. Observe the behavior of the animals. What type of tropism is seen?
3. Bind very small seedlings against glass plates with moist blotting paper and string. Stand each plate on its edge and allow the roots to grow. Every day or two replenish the supply of water and change the position of the seedlings. What kind of tropism is shown?

[1] Other kinds of tropisms:

1. Phototropism—response to light.
2. Thermotropism—response to changes in temperature.
3. Geotropism—response to gravity.
4. Thigmotropism—response to contact.
5. Hydrotropism—response to water.
6. Chemotropism—response to chemical substances.
7. Galvanotropism—response to electricity.
8. Anemotropism—response to air currents.
9. Rheotropism—response to water currents.

NOTE.—When pronouncing the names of the different tropisms the accent falls on the *ot* in each case

Review

1. What is a tropism?
2. When is a tropism positive; when is it negative?
3. What different stimuli may produce tropisms?
4. Why must plants and animals which are larger than single cells, be more specialized than single-celled forms?

Define

gravity **nutrition** **positive tropism**
negative tropism

UNIT VIII

THE CONTINUANCE OF EACH SPECIES OF PLANT AND ANIMAL DEPENDS UPON THE SUCCESS OF ITS METHOD OF REPRODUCTION

CHAPTER XXXIII

REPRODUCTION BY THE INDIVIDUAL IS COMMON AMONG BOTH THE LOWER PLANTS AND THE LOWER ANIMALS

484. The simplest way for a plant or an animal to reproduce is to divide into two parts, each part becoming a complete organism.

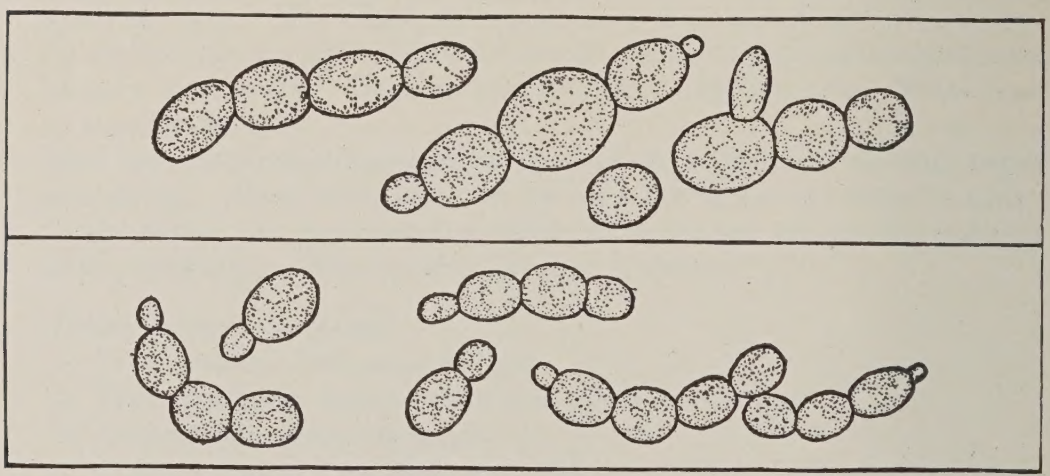


FIG. 246.—The yeast plant is a single cell. It reproduces by a process known as budding, as illustrated here. (*Atwood and Heiss.*)

And this method we discovered to be the usual one among the simplest plants and animals, that is, the one-celled thallophytes and the protozoa. Budding, which we first studied in yeast plants, and later noted in hydra, is employed in animals as com-

plex as the flatworms and it is occasionally used by certain of the highest plants.

485. We found that conjugation, a kind of sexual reproduction, is present among the simpler plants and animals such as spirogyra and paramecium, but it is of no great comparative importance. Among plants the asexual method continues to be more prominent than the sexual method through the moss and fern

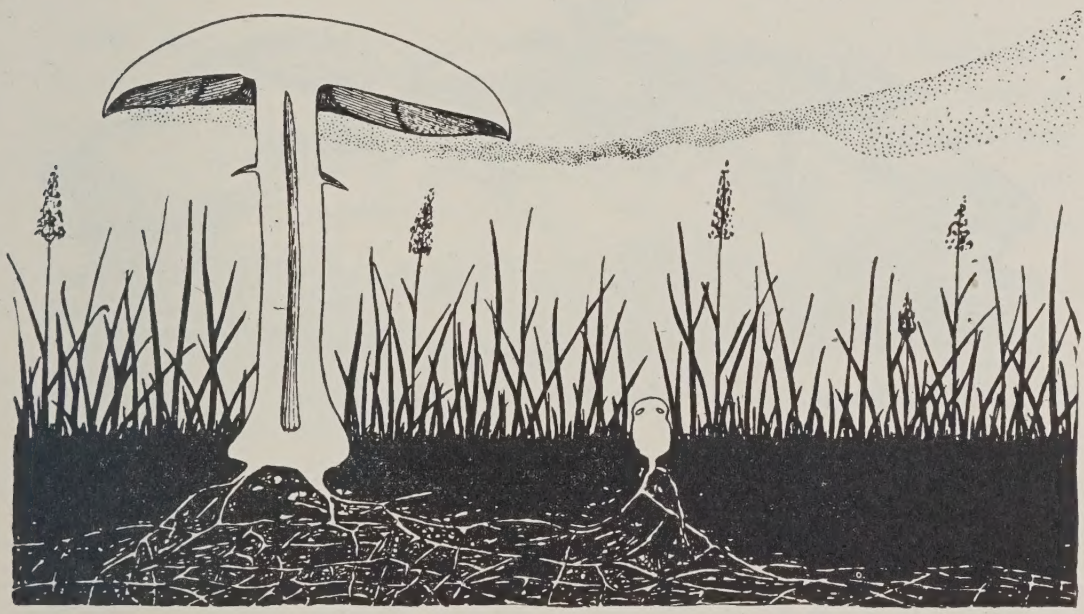


FIG. 247.—Drawing to show the method of growth of the mushroom, and its method of scattering spores. Here we see the spores being carried to the right by a slight movement of air as they drop from the umbrella-like top. A full grown mushroom and an early stage are developing from the same root-like mycelium. (*Gager.*)

groups, leaving the higher plants with their complex seed-producing mechanisms to remind us of the importance that sex eventually attains among plants.

486. Sex in animals appears early; definite modifications as sex cells are noted in sponges and coelenterates. Especially among the lower invertebrates we often find both kinds of sex products produced in the same organism, a condition common in most of the plant groups. We discovered, however, that this is not the usual condition in the majority of the animal groups.

487. Reproduction without sex lessens the possibility for variation within a species, because only one parent contributes characteristics to the offspring. A more rapid progress in the development of new and better adaptations is derived by the natural selection which results when there is a large number of variations, because some of them will naturally be better equipped to survive than will others. Therefore, from the evolutionary

FIG. 248.—A few plants, including the begonia, may be propagated from leaves. (*Gager.*)

standpoint, asexual reproduction is less efficient than the sexual method.

Interesting Projects

1. Make drawings to show how the amœba divides by fission, and the hydra by budding.
2. Under what conditions do plants and animals reproduce only by asexual methods?
3. Look at the drawings of conjugation in spirogyra and the same process in paramecium, and write a description of the differences you observe.

Review

1. What is the simplest method of reproduction?
2. How does fission differ from budding?
3. How does conjugation differ from fertilization?
4. Why does reproduction without sex lessen the possibility for variation within a species?
5. Why is there a natural selection among the variations in a species?

Define

budding **natural selection** **variation**
hydra

CHAPTER XXXIV

THE MORE COMPLEX PLANT OR ANIMAL IS USUALLY DERIVED FROM TWO INDIVIDUALS

488. As a rule, sexual reproduction implies greater complexity of structure than is present in the lower organisms because among the higher plants and animals special organs are developed which are adapted to produce modified cells, a condition not necessary for fission or budding. These specialized structures

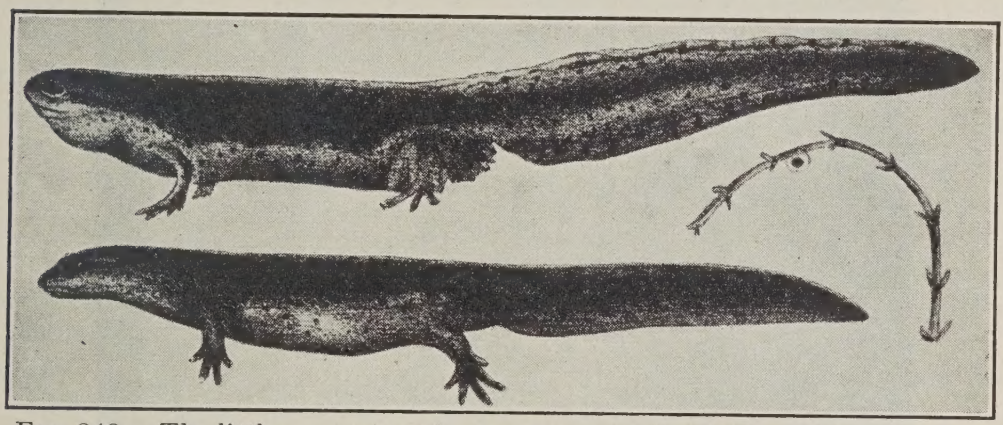


FIG. 249.—The little green American newt may often be found in quiet ponds. The female (below) attaches her eggs singly to leaves or water plants as shown at the right. She lays a few eggs at intervals throughout the breeding season. The male is shown above. (*Lane from Gage.*)

are of two general types; one, the female, provides cells or nuclei with an abundance of stored food. These cells or nuclei are consequently unable to move about. The male produces cells or nuclei with little stored food, but with adaptations for movement so that they may eventually reach the female nuclei to unite with them.

489. Among plants, it is customary for both the male and female products to be produced in the same organism, and self-fertilization is common as among the mosses and ferns. Many

seed-bearing plants take elaborate precautions, as we have already learned, to **avoid** self-fertilization, although it is sometimes employed in conjunction with cross-fertilization. The

FIG. 250.—Stages 1 to 6 show the development of the cucumber fruit from the fertilized pistillate flower. No. 7 shows the staminate flower which supplies the pollen grains. (*Robbins and Ramaley.*)

presence of both kinds of sex products is found among some of the lower animals such as certain species of sponges, coelenterates, and worms. This condition is especially helpful to

parasitic animals such as the human tapeworm, because often only one organism gains entrance to the host. But when we study all of the animal groups we learn that the usual arrangement is to have each kind of sex product produced in a separate kind of organism.

In the highest development of this bi-sexual method, as among the birds and mammals, there often occurs a parental care and responsibility which result in desirable social customs, such as the founding of homes, protection and care of the young, and mutual helpfulness.

Interesting Projects

1. Make a copy of the drawings of the different stages in the life cycle of the fern plant. Label the stages which are asexual and those which are sexual. Do the same with a coelenterate which has a sexual stage alternating with an asexual stage.
2. Write a brief comparison of the period of helplessness of the young bird or mammal and the adaptations for parental care.

Review

1. What are the two kinds of specialized structures found among the seed-producing plants which produce the pollen grains and the ovules?
2. What are the two kinds of specialized structures found among animals which produce the egg cells and the sperm cells?
3. How does the necessary parental care of the young among human beings contribute to the development of communities?

Define

coelenterate **parasitic animal** **parental care**
host

CHAPTER XXXV

IN NATURE, PRESERVATION OF THE SPECIES IS MORE IMPORTANT THAN PRESERVATION OF THE INDIVIDUAL

490. The species of plants and animals which are successful in their endless competition with the environment and with their natural enemies show many interesting adaptations. Every sportsman knows that the fur of most animals in the northern latitudes becomes thicker at the approach of cold weather; that ducks and geese are likely to migrate southward earlier before extremely cold winters; that some species of weasels have white fur while snow is on the ground; that the ruffed grouse develops a "web" between the toes during the winter for walking on the snow. These are but a few of the common observations showing adaptations of animals at one season of the year. Likewise many species of plants are protected against extreme cold by the woolly covering over the buds. Others are protected against undue loss of water by shedding their leaves. Such forms as cacti can store water in their stems and thus withstand prolonged drought. Thus it is always evident that there is a constant struggle to survive being waged by each living thing.

491. But plants and animals are often overcome by the forces of their environment or by preying enemies before their numbers have been replaced by their own reproductive processes. This fact makes necessary a method of reproduction for each species, *if the species is to survive,* which will provide for a larger number of offsprings than there are adults. For this reason an over-production is evident among all successful species of living things. It has been estimated that if all the eggs of the codfish were allowed to develop into fishes, within a few generations the sea

would lack sufficient room for them. If all the eggs of the English sparrow hatched and developed to maturity, these birds would overrun the earth within ten years. Among plants, such

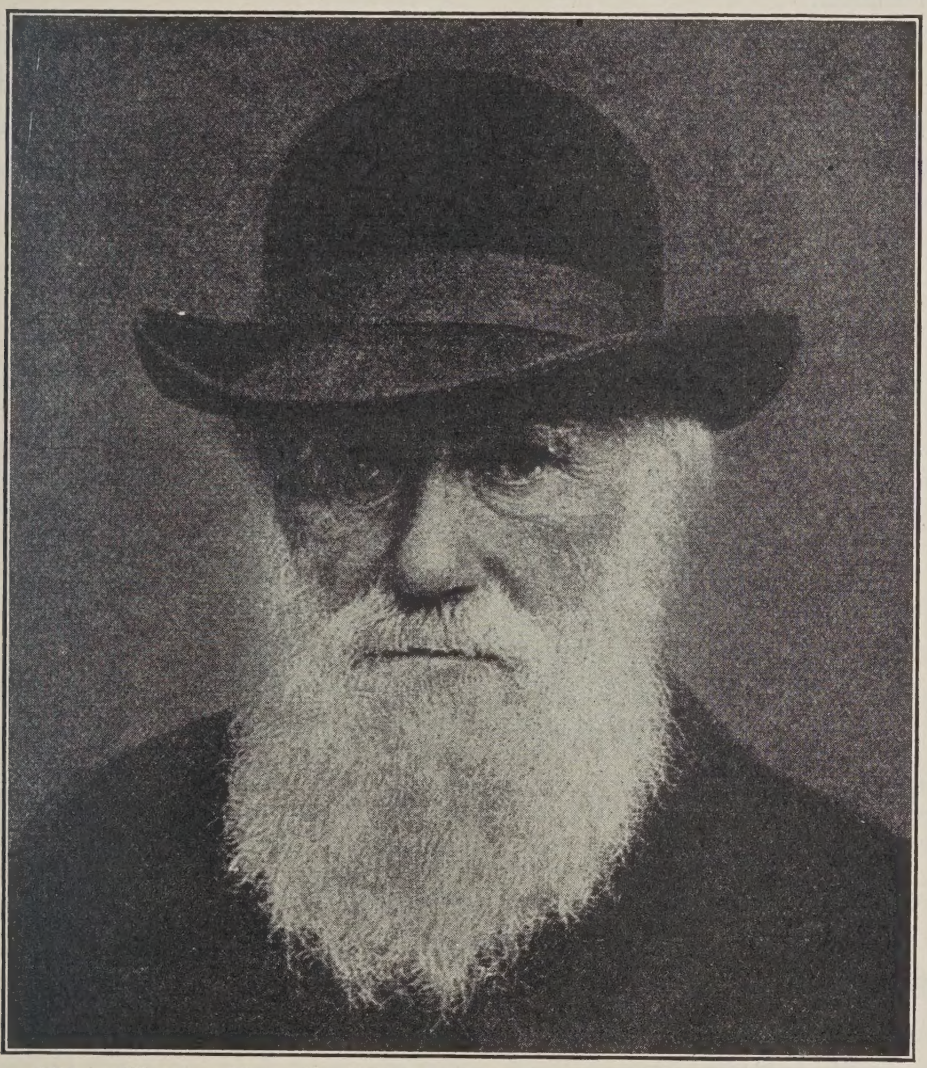


FIG. 251.—Charles Darwin (1809–1882), developed the idea that there is a natural selection among plants and animals; that the plants and animals best adapted for their environment are the ones most likely to survive. Thus they will reproduce others having similarly favorable adaptations. (*Gager.*)

enormous numbers of seeds are produced by plants like the milkweed and the dandelion, that if unchecked, there would soon be no unoccupied soil for their roots. Thus the factor of competition has brought about a condition which results in the

production of more individuals than could possibly survive. In fact, if all other restrictions were removed from a given species, the individuals of that group would soon be in competition with each other.

By producing a sufficiently large number of plants or animals to make up for those which do not survive, death of the individual has its compensation in nature's scheme. The life of the species is continuous until environmental changes bring about either

FIG. 252.—The Cecropia moth, one of the most beautiful of our common moths has many enemies. Like most insects, its survival is due to an ability to reproduce in large numbers.

the formation of new species by modifications in structure, or else the annihilation of the group.

492. Man, by the use of his intelligence, has interfered in many ways with the ordinary processes of nature. He has protected certain plants and animals and has caused them to develop along lines to suit his needs. Such animals as the modern dairy cow would be quite helpless in competition with wild forms. On the other hand, he has nearly exterminated the bison, an animal type which had been successful in its competition with other organisms.

But man, like all other organisms, submits to nature's law that the species is more important than the individual. Occa-

sionally hope is revived by such experiments as those of Dr. Alexis Carrel and Colonel Lindbergh, in which organs are kept alive outside the animal body, that man may sometime have an immortal body. Probably the realization of such a hope will never be realized. This, however, does not discourage attempts to improve the lot of those now living. Oftentimes succeeding discoveries, based on earlier results, have far-reaching benefits which could not be foreseen. It is possible that valuable facts about abnormal cell growth, such as occurs in cancer, will be learned from the results of the Carrel-Lindbergh experiments.

Interesting Projects

1. Certain kinds of bacteria reproduce every thirty minutes, when conditions are favorable. Starting with a single one at ten o'clock in the morning, and assuming that all the offsprings live, and that each one reproduces once, determine how many bacteria there would be at the end of twenty-four hours.
2. From a textbook on geology, give examples of species of plants and animals which have become extinct.

Review

1. Why is an overproduction of offsprings necessary in any species of plants or animals? Give examples.
2. How would the development of any species of plant or animal be affected if the factor of competition could be removed?
3. Why is the process of reproduction necessary among all plants and animals?

Define

maturity **offspring** **overproduction**

UNIT IX

SPECIES OF PLANTS AND ANIMALS BECOME CHANGED BY VARIATION AND HEREDITY

CHAPTER XXXVI

VARIATION MAKES POSSIBLE THE SELECTION OF THOSE SPECIES WHICH ARE BEST FITTED TO SURVIVE

493. Why are the finger prints of criminals and many other persons recorded for identification? It is because faces and other

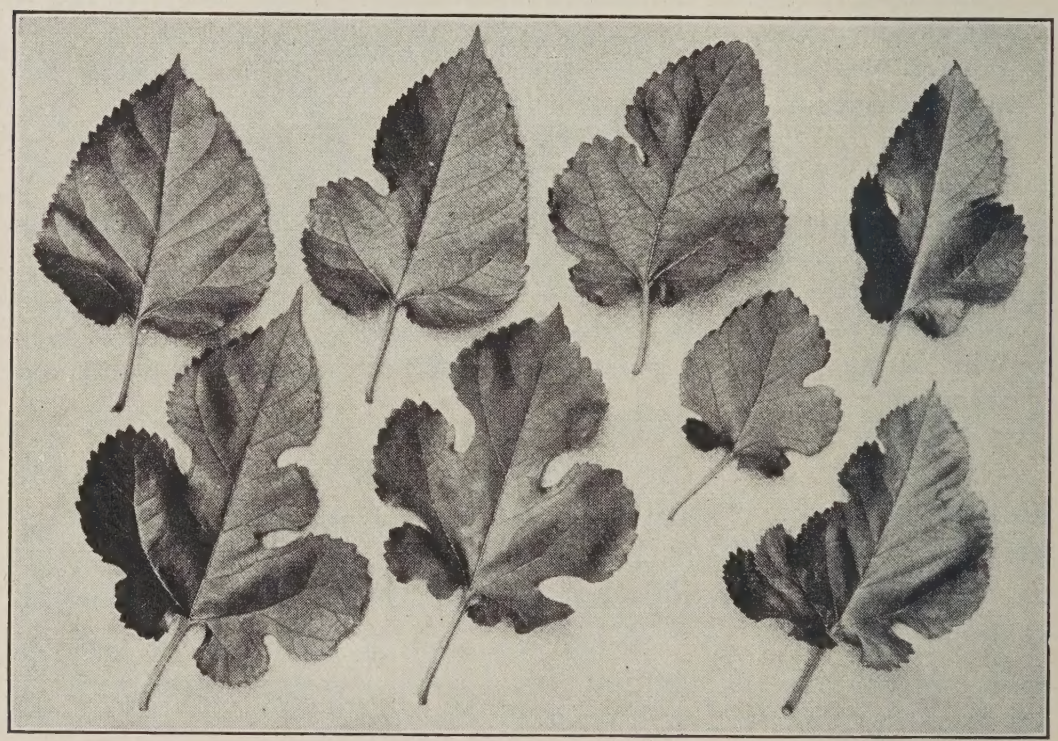


FIG. 253.—Variation in mulberry leaves from the same tree. (*Gager.*)

characteristics may be so much alike that positive identification is impossible. But the finger prints of one person are never exactly like those of any other person.

Nature never duplicates. The Law of Variation states that **no two individuals are exactly alike.** Does this mean that no two of the millions of blades of grass in a field are alike in every detail of structure? It means just that. If you had the patience, you could probably find hundreds of them which are exactly the same length, width, shape, and color. But if you placed these under high magnification, you would not have the slightest difficulty in noticing differences of cell arrangement and even different numbers of cells.

494. Many investigators have assembled a large amount of data bearing upon the facts of variation among living things. One investigator examined 178 individuals of the common California flower beetle, and found no two of them exactly alike. The same was found true of 58 specimens of Cardinal grosbeaks, which Dr. J. A. Allen collected and measured, several years ago. "And anyone with means of collecting a considerable series of individuals of single species can, if he but give the time and study to it, reveal similar variations in almost any part or characteristic of any species or kind of plant or animal."[1] This fact may or may not be surprising, but its importance is great, as we shall see in the following section.

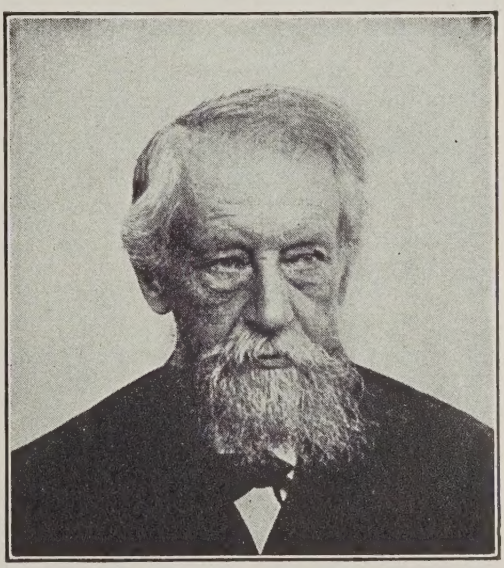


FIG. 254.—Hugo de Vries (1848–1934), the Dutch botanist, believed that many new species of plants and animals appear suddenly as offsprings of organisms already known. He called these new kinds of organisms *mutants*. (*Gager.*)

495. Mutations.—From time to time there appear, among most species of plants and animals, variations, often more outstanding than usual, which are heritable. The name "mutation" (*mū-tā'-shun*) was given to

[1] *Evolution and Animal Life*, Jordan and Kellogg, Appleton.

them by Professor Hugo de Vries, the Dutch botanist. A mutation thus appears as a distinctly wide variation, a sort of offshoot from the normal type of its race. It is sometimes very noticeable. Let us study three illustrations:

FIG. 255.—The original concord grape vine and its originator, Ephraim W. Bull. (From an old print purchased in Concord, Mass.) (*Gager.*)

496. In 1770 a calf was born in Paraguay which, as it matured, failed to develop any horns; a distinct variation from its parents and the other members of its species. This mutation was dominant, i. e., none of its offsprings ever developed horns. In the one hundred and sixty-six years since then, that desirable quality, hornlessness, has been bred more or less into nearly all breeds of

cattle in many lands. A new line—hornless cattle—was thus started from that one mutation.

497. In Concord, Mass., there appeared on a grape vine in a certain garden, a cluster of grapes that were slightly larger and better flavored than those of the surrounding clusters on the same vine. Short pieces of this stem, known as "cuttings", were

FIG. 256.—Four-legged chicken. Animals such as this one are known as freaks. In all such cases the abnormal structures are never passed down to their offsprings. (*Courtesy of Fallot Studio.*)

placed in moist soil to develop roots, thus forming new plants, and this was the beginning of our common Concord grapes.

498. On the island of Malta, a six-fingered person was born—so Huxley tells us in his "Essays". The strange thing about it was that that person's descendents were all six-fingered. This variation was dominant and continued for many generations. It would not be difficult to list a large number of new races each

of which started from a single mutation. It is generally agreed that mutations have done much in the way of bringing about the many changes in all races of living things even before man began domesticating and breeding plants and animals.

499. Freaks.—Certain types of albinism (*al'-bin-izm*) (the absence of coloring matter in the skin, fur, feathers, etc.) are sometimes seen among different species of animals. The four-legged chicken shown in Fig. 256 which lived for several weeks, or the two-headed or five-legged calf you may have seen in some museum or circus are good examples of variations which occur spasmodically, from time to time, as freaks—offshoots from the usual types of their races. A freak, then, may be defined as a **large or noticeable variation which is not heritable.**

FIG. 257.—Tobacco plant affected by black root rot (at left). Plant of same age, immune to the disease (at right). (*Conn. Agricultural Experiment Station photo.*)

500. Plant and Animal Breeding.—New breeds of poultry, horses, dogs, roses, apples, and many other forms testify to the plant and animal breeder's ability to produce new breeds of living things. He employs not only the method of cross-breeding, or "hybridizing" as it is often called; he is ever on the alert for new variations, as they appear from time to time, and often breeds from them.

501. Between 1927 and 1930, Mr. John G. Wolf of the Connecticut Agricultural Experiment Station at Windsor, Conn., produced a strain of tobacco plants which has proved to be immune to black root-rot. This disease, by killing the roots, often stunts or destroys whole fields of Cuban shade-grown tobacco. By persistent search among the infested fields, Mr. Wolf finally found a mutation which proved to be immune to this disease. Figures 257 and 258 show the very

marked difference in the size and rate of growth of this new strain, when compared with the ordinary Cuban tobacco, which is susceptable to the disease. That the tobacco growers readily appreciate the value of this immune variety is shown by the fact

FIG. 258.—Shade-grown tobacco. The row of plants in center are stunted because of the black root-rot disease. The mutations at each side are immune to the disease. This is an example of breeding for immunity. (*Conn. Agricultural Experiment Station photo.*)

that their demands for seed are far greater than can yet be supplied.

The commercial plant and animal breeders are also stimulated by the constant demand of the buying public for "something new"—a new variety of roses, or perhaps a new breed of pet dogs.

502. Most plant and animal breeders work with fairly definite aims in view. They often breed from promising stock, which,

possessing desirable characteristics, is popular and in demand. From this stock they may produce that "something new," and this may also prove to be very profitable. At other times they work toward a previously conceived type of plant or animal, and, if they succeed, this will be not only new, but also valuable. Then, for their stock, they go to those breeds which at present come the nearest to having the particular qualities they have in mind. They discard the most of the crop or litter and keep only those which come nearest to their ideal, then breed from them again and again. Sometimes they succeed—and another new breed is produced.

Thus variations make changes in species possible, either with or without man's help, and these changes enable the best fitted to survive.

Interesting Projects

1. On a field trip, carefully gather one hundred blades of grass, taking care to cut them close to the ground. Arrange these according to length. If any two are of the same length, compare them as to width; then as to shape and, if necessary, examine under the microscope as to number and arrangement of cells at the tip. Can you find any two which are exactly alike?
2. Throw a handful of grain among the fowls in a poultry yard. Do they all seem to get an equal amount of the food? What effect has the variation of quickness upon the amount of food that such individuals obtain? Name a few wild animals to which quickness is even more important than it is to these fowls.

Review

1. Define a mutation. Give an example of the practical use that has been made of a mutation.
2. Would favorable or unfavorable variations be more likely to be handed down by heredity? What are your reasons for thinking so?
3. Since wild animals probably differ as much as do people in regard to their sense organs, what would probably be the fate of a hawk having defective sight, or a deer having a poorly developed sense of smell? What reasons can you give for your answer?
4. Have you ever noticed whether any consideration is shown a sick bird in the poultry yard, by the other individuals? If it is not, what would

you expect to be the result? Is it true, other things being equal, that the strongest usually survive?

5. Do you notice considerable variation among the members of your class as to their ability to get high grades? Does it seem to you that all men are created mentally and physically equal?
6. Can you find four or five outstanding characteristics possessed by certain leaders in our national life at the present time? Name these characteristics.

Define

albinism	**hybridize**	**normal type**
dominant	**mutation**	**variation**

CHAPTER XXXVII

THE CHARACTERISTICS OF A SPECIES ARE TRANSMITTED BY HEREDITY FROM ONE GENERATION TO THE NEXT

503. A small orphan child was brought to a social service agency. They had his complete history and found that his parentage was very undesirable. The boy, however, was such a quick, bright little fellow that the worker took him to a reputable physician who was a child specialist. Blood tests were made. A careful and thorough physical examination was given. Likewise a psychological test adapted to a child of his age was given and passed very successfully. All the results of these procedures being distinctly favorable, the social worker turned optimistically to the physician, saying "Then you think, do you not, that that dark parentage will not stand in the way of his developing into a fine boy, and later into a strong man?"

In the face of seemingly positive evidence of nothing to the contrary the physician thoughtfully shook his head. "If you plant a cabbage, you will raise a cabbage" he said. "You may put this boy into a good home, and work wonders with him. In the same way, you can give a cabbage such culture that it will be almost a cauliflower—**but it will still be a cabbage".** Such was his faith in heredity.

504. Just how far heredity is a ruling factor, we shall see presently. Most certain it is that, to some extent at least, we are able by constant effort on our part, to overrule a certain amount of our mental and physical inheritance—such factors as natural slowness, lack of ambition, initiative, and muscular development.

But just what is heredity? It is a sort of guarantee that the young animal or plant will be very much like its parents. The

law of heredity states that **for the most part, offsprings resemble their parents.** Some persons doubt the facts of heredity, saying that they have seen children who did not resemble either parent. Superficially, this may seem true but we must look further.

Why does the offspring of a bird possess a bill like its parents, the body shape of its parents, a heart and lungs like those of its parents, and, as it grows up, feathers and plumage like that of its parents? Obviously it is heredity. It is only by **heredity** that

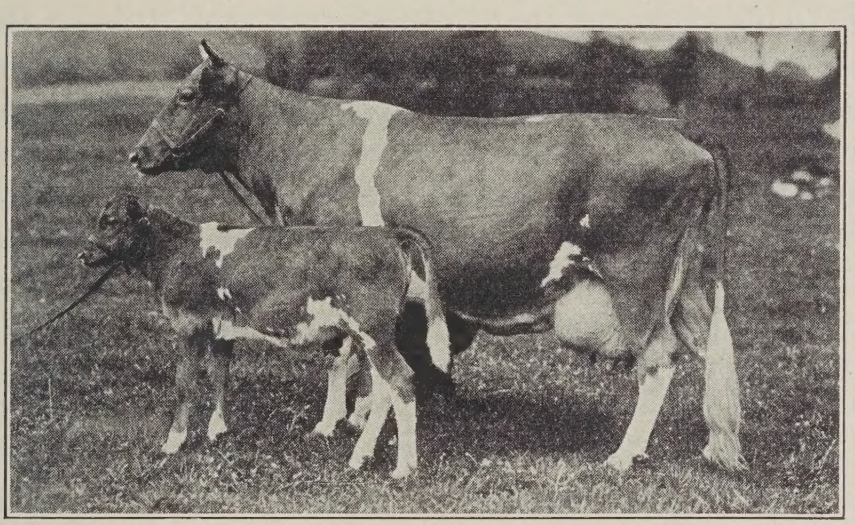


FIG. 259.—Guernsey cow and calf. This breed has been developed for its large production of butter-fat. Note the resemblance between the mother and her offspring. (*Courtesy American Guernsey Cattle Club.*)

every young plant and animal develops those characteristics which distinguish it as a member of the same species. Likewise, by heredity, those characteristics are passed on to the future members of the race.

505. The Mechanism of Heredity.—Various attempts have been made by one means or another, to improve or to change the nature of certain races. Weismann, a noted student of heredity, proved that it is impossible to produce a race of short-tailed mice by cutting off their tails for a number of generations. In every instance the offsprings have full-length tails. Fruit trees which have been pruned to produce well proportioned trees do not have offsprings which show the slightest benefit from this pruning. These facts show us that in order for any change to become

heritable it must be so thoroughly a part of the organism, that it becomes established in the reproductive cells and therefore is passed on by the germ plasm, which is the protoplasm of the sperms and eggs.

506. Such man-made changes as the mutilated tails of Weismann's white mice are superficial in that they do not form a part of the "warp and woof" of the very animal itself. Hence we can say that **nothing is heritable unless it becomes a part of the germ plasm.** This shows us that only what is passed down through the sperm and egg cells can control or determine what the new organism shall be. Weismann's experiment demonstrated that if mutilations of this kind or that could be passed down by heredity, we should soon have a race of cripples.

507. The Bearers of Heredity.—What then, are the essential structures which determine what the young animal or plant shall become—what characteristics it shall possess?

Every species of the higher animals and plants is made up of cells. And within the nucleus of every cell is the material which forms a fixed and definite number of microscopic bodies called **chromosomes.** This number is always the same among the members of that species. (There are 48 in the human race.) Now the presence or absence of certain parts of the chromosome, called **genes** (*jēns*), determine whether the offspring shall or shall not possess the particular characteristics which these genes control.

In a word, it is the chromosomes in the nuclei of the sperm and egg cells **which are the bearers of heredity.** These bodies have been seen, counted, and studied under very high-powered compound microscopes, and their presence and function are now a certainty.

508. Research students in the larger experimental laboratories of heredity are now able to tell by the presence or absence of certain genes in the chromosomes, whether fertilized eggs of the common fruit fly will produce offsprings having gray or black bodies, long or short wings, light or dark colored eyes, and other physical characteristics. Thus it is now known that the chromo-

somes determine what characteristics will, and what ones will not, appear in the offspring.

509. The Offspring is a Part of the Parents.—It has been said that "the child is father of the man." Every new organism is a product made up of the accumulation of all its ancestors. The qualities such as tallness, shortness, brown eyes or blue, fondness for music or indifference to it, quickness or its opposite, native skill at this or that, have all come from its parents directly and from all its other ancestors indirectly. Of course skill in playing the violin, for example, is the result of long practice; but it is also probable that an innate love for music, which came by heredity, was the real reason for studying the instrument in the first place.

510. How Heredity Works.—These facts show us that heredity is not a matter of chance. "We must play the game of life with the cards that are given us." This is only too true. The cards are our brain, our body, our health, our strength—all of which came from our ancestors.

Heredity has been so tremendously important in fashioning the changes that have come about in the different species of living things that we shall do well to ask ourselves what heredity has done, except to hand down certain qualities. We shall see that in the process of transmitting these qualities new combinations of characteristics have arisen—and hence, another method of producing new species.

511. The Work of Gregor Mendel.—There once lived, in the monastery in Brünn, Austria, a monk named Gregor Mendel. It is said that his gardens around the monastery attracted much attention because of the variety and color combinations of his flowers. He had noticed that when he kept the seeds from certain flowers and planted them the next year, they sometimes produced plants just like those of the parent plant, and sometimes produced others which were very different. Being somewhat curious about it, he sought to find out the reason for the differences in them.

512. For his experiments, he chose the common garden peas. He learned that if he planted seeds from the shorter, dwarf

varieties of plants in a plot by themselves, they always produced dwarf plants the following year; but if he planted the seeds from tall plants in another plot by themselves, they sometimes produced tall plants only, and sometimes short plants. This fact caused him no little wonder and he attempted to learn the cause.

513. He knew that the blossoms of pea plants, like those of any others, have to be pollinated before they will produce any

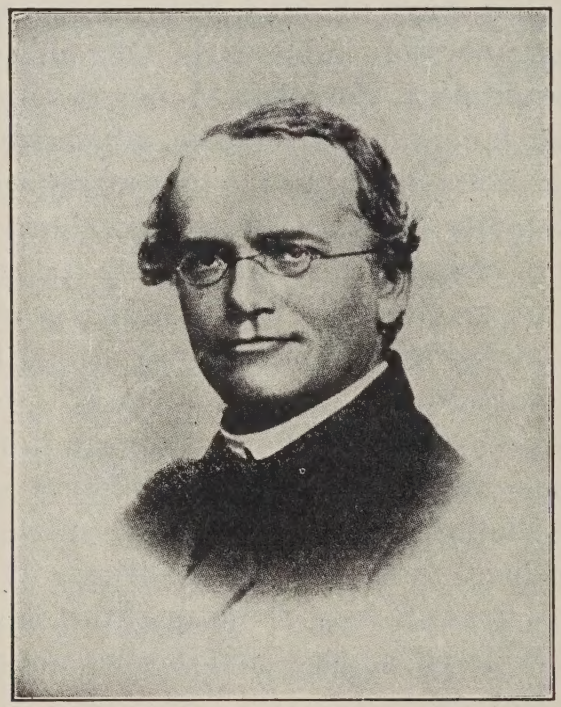


FIG. 260.—Johann Gregor Mendel, (1822–1884), the Austrian monk, discovered the laws of heredity which explain the resemblance between parents and their offsprings. (*Gager.*)

fruit and seeds, so the question arose as to how they were pollinated. He recalled that when he planted the seeds from tall plants which had come from a race, **all of which had been tall for several generations,** that their offsprings invariably produced the tall variety. These he felt sure of, and called them **"pure-bred,"** since they always bred true. Likewise, the dwarf plants which always produced offsprings like themselves, he called **"pure-bred",** for the same reason.

514. The Law of Dominance.—Mendel then cross-pollinated the blossoms of these tall and dwarf plants, by carefully removing

the stamens from the blossoms of one variety, and putting pollen from the other variety, upon the stigmas of the first ones. Every single offspring of this first or F_1 generation, was a tall plant. This experiment he repeated, each time getting the same result. Since tallness predominated and seemed to crowd out the dwarf variety, he stated that **in garden peas, tallness is dominant.**

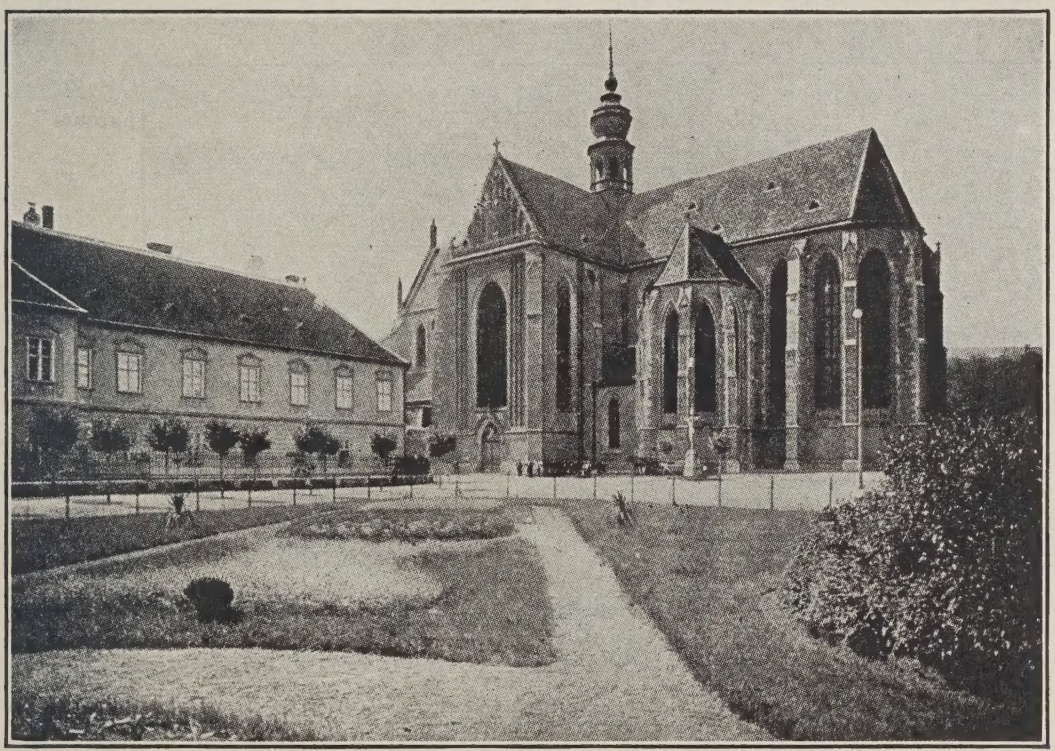


FIG. 261.—The monastery at Brünn. It was in the adjoining gardens that Mendel discovered the Laws of Heredity. (*Gager.*)

From this, he formulated the law of dominance. This law states that when individuals which differ markedly from each other in some respect, are mated, the offspring will resemble one parent, and not the other (in this respect).

515. Unit Characters.—Mendel called this one factor of height in garden peas a **unit character,** (a characteristic which remains unchanged when passed down from one generation to the next). He also experimented on many other unit characters, such as green color vs. yellow color in the pea seeds; smooth seeds vs. wrinkled seeds, and other opposing characters. In each of these

pairs of unit characters he learned, by repeated experiments, which character was **dominant,** or ruled over the other. He also gave the name "recessive" to the character that was seemingly crowded out.

516. The Idea of Segregation.—Mendel then questioned whether these hybrid peas would breed true and produce others like themselves. You see, a hybrid is any organism whose

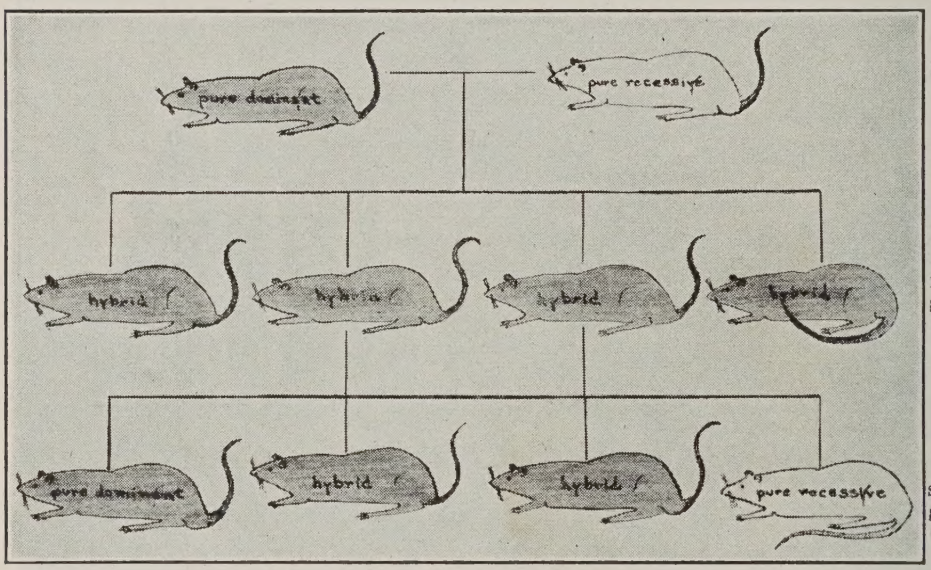


FIG. 262.—Diagram showing the first and second hybrid generations in rats.

parents are both pure bred but are of two different varieties. So he cross-pollinated two of the blossoms from these hybrid plants of the F_1 generation and, later, saved the seeds which developed, to be planted the following spring. What must have been his surprise to find, the next year after the plants which came from them were fully grown, that about **one quarter** of the plants were short! The rest of them were tall.

Mendel kept the seeds from both species and repeated the experiment the following spring. The dwarf plants continued to produce pure-bred plants. He had produced a pure-bred variety from parents which were hybrids!

517. The problem was not so simple with the tall plants. About one third of *these* (that is, about one quarter of *all* the

plants) produced pure-bred tall plants like themselves. But the other tall plants, when self-pollinated, produced some pure-bred short plants and twice as many tall ones. A study of the accompanying charts will make these statements clear.

518. We can summarize what we have thus far learned about Mendel's breeding experiments, as follows: whenever pure-bred organisms are crossed or mated with pure-bred organisms, which differ in one or more respects, the offsprings (called F_1) are hybrids, and appear like that parent which has the dominant

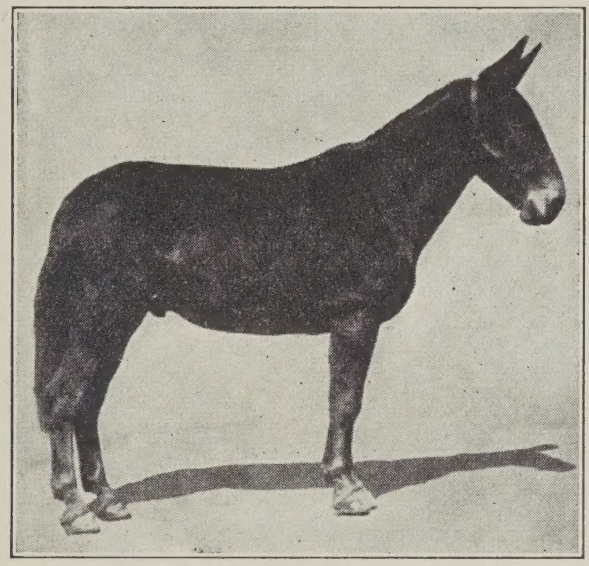


FIG. 263.—The mule is a hybrid whose parents are a horse and a donkey. (*Corwin and Corwin.*)

characteristic. Each organism has many characteristics. In fact, some characteristics may come from one parent and some from the other parent. In every such case the offspring will possess **those characteristics which are dominant, regardless of which parent they came from.** But in the F_2, or second hybrid generation (which are the first offsprings of the F_1 generation), there are 25% pure dominants, 25% pure recessive and 50% hybrids. There is no such thing as a "pure" hybrid, since by its very origin, it is a cross.[1]

[1] Hybrid is used here in the technical sense. The term is often used commercially to mean any crossing regardless of purity of parentage.

519. The Law of Segregation.—In the second hybrid generation there appear pure ancestral types (as pure-bred as their grandparents were) among the offsprings of the hybrids. And this has been proved true of animals as well as plants, and works out the same way in every F_2 crop, or litter of young. Much experimental work has been done with guinea pigs, rats, dogs, and various breeds of poultry, where the law holds equally true, as can be seen in the accompanying diagram.

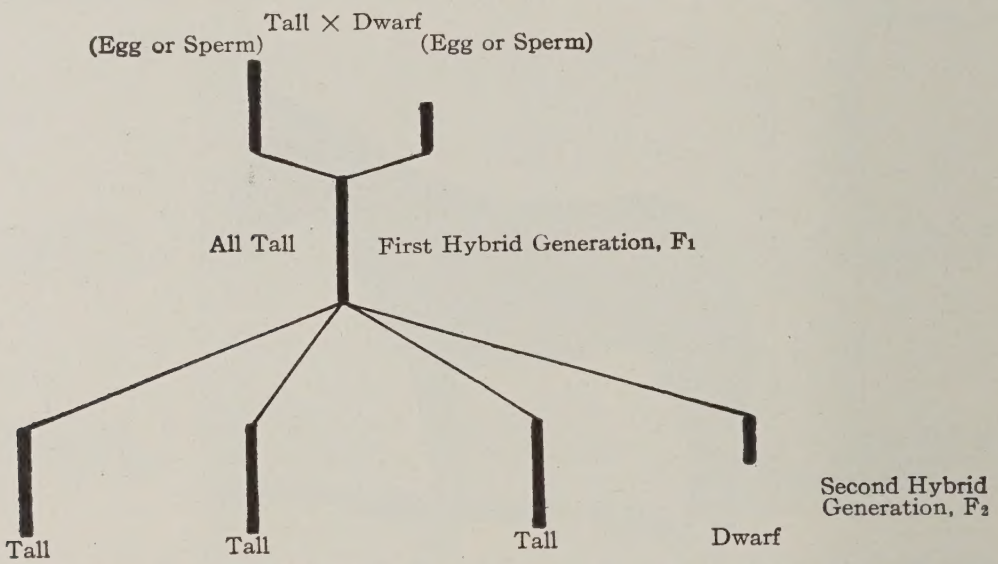


FIG. 264.—It is important to note that all the organisms of the first hybrid generation (F_1) are alike. We should also note that we cannot tell by their appearance which of the tall plants of the F_2 generation are pure-bred until we breed them. (*Mottier.*)

Two outstanding facts are shown by this second hybrid generation; first, that the recessive characters reappear, after being seemingly crowded out of existence; second, that it is possible to secure pure-bred organisms from parents which are hybrids.

520. Artificial Selection.—Mendel's work well illustrates what is termed "artificial selection." It simply means that man selects the parents which have those qualities that he is working to establish. He then breeds those animals or plants together. Natural selection, on the other hand—the cross-pollinating of uncultivated plants and the mating of wild animals—is done by

Nature, not by man. Flowers get pollinated by the wind, and water, as well as by insects, birds, and other animals; animals select their mates with no regard whatever (except in the case

FIG. 265.—The double dahlia; a hybrid type obtained by selection and cross-pollination. (*Robbins and Ramaley.*)

of man) as to what the offsprings may be. But think of the wonderful variety of new species of shrubs and flowers that you see in our parks and gardens, whose very existence is due to man's study and research along the lines of artificial selection.

Interesting Projects

1. Make a list of the characteristics of some friend of yours. Include such characteristics as color of eyes, color of hair, disposition, or special talents. Then observe his parents and try to discover whether each of these characteristics came from the mother or the father. If in some instances you are not sure, see if you can trace them to one of the grandparents.
2. Ask some breeder of plants, such as a florist or a fruit grower, what particular characteristics he desires in the plants that he breeds. Then inquire how he goes about it to obtain these desired qualities in the new plants.
3. Try to discover for yourself whether you more closely resemble your mother or your father. If you know of some unusual likes or dislikes or, perhaps, some physical characteristic noticeably different from either parent, ask one of your grandparents to help you trace it back. In most cases you will succeed in locating each one of your characteristics.
4. Make a list of five boy or girl friends who closely resemble their parents. In what ways does each one show resemblances?
5. Select four breeds of dogs, and from the encyclopaedias find out the origin of each breed.
6. Write an account of the problems and accomplishments of Luther Burbank.

Review

1. How can we take advantage of our environment to counteract in some measure any unfavorable part of our heredity?
2. How is it possible to get pure-bred plants or animals from parents which are hybrids?
3. How is it possible to develop a race of organisms which will be immune to certain diseases?
4. What natural law makes possible the identification of criminals and other persons by the process of finger-printing?
5. What is the relation of variation and heredity to plant and animal breeding?
6. State two aims in the practical breeding of either plants or animals.
7. What advantage is gained by those farmers who plant northern-grown seed potatoes?
8. How do plant and animal breeders find out what characteristics are dominant and what ones are recessive?
9. Would you expect yellow-seeded garden peas, purchased at the store, to breed true? What reasons can you give for your opinion?
10. What particular qualities would a plant breeder try to establish in a new variety of roses? apples? cantaloupes?

11. How was it proved that "nothing is heritable unless it becomes a part of the germ plasm"?
12. Describe the aims as well as the general practice of artificial selection.

Define

artificial selection	**generation**	**pollen**
characteristic	**hybrid**	**pure-bred**
chromosome	**inheritance**	**recessive**
gene	**mutilation**	**self-pollinate**

CHAPTER XXXVIII

THE PRINCIPLES OF EUGENICS MAY BE USED FOR THE IMPROVEMENT OF THE HUMAN RACE

521. As we have come to understand and apply the principles of heredity to the scientific breeding of plants and animals, there is a growing belief that these principles may be the solution to many of our social problems. It is generally recognized by leaders in the medical profession that much of the disease, both mental and physical can be traced to weaknesses or tendencies that are heritable. Likewise the handicaps caused by defects of various kinds are, in many instances, traceable to defective parentage and unfavorable environment during childhood. Strong, robust, healthy persons develop into the kind of people they are today because they inherited from their ancestors those physical characteristics which were improved by a favorable environment. And the opposite is equally true. Weak, sickly and ambitionless people inherit from their parents bodies and minds lacking in physical and mental strength and alertness. In all too many cases they grow up in surroundings that are not conducive to the development of health and ambition.

522. The science of **eugenics** (*u-jen'-iks*) may be defined as being born well and strong, both physically and mentally. It means that the child shall come into the world without a tendency toward tuberculosis, diabetes, feeble mindedness or other handicap to keep him from developing normally.

523. Three Family Histories.—The histories of three well known families will serve to show us the importance of being well born. Let us compare the story of the Jukes family with that of the Kallikaks, and then with the record of Johnathan Edwards' descendents:

In the notorious "Jukes" family, the father was lazy and with no ambition. Among his descendents, fully one third died before reaching the age of one year, and among the others more than 1500 were feeble-minded. There were 310 paupers, besides several thieves, murderers and others who lowered the standards of society.

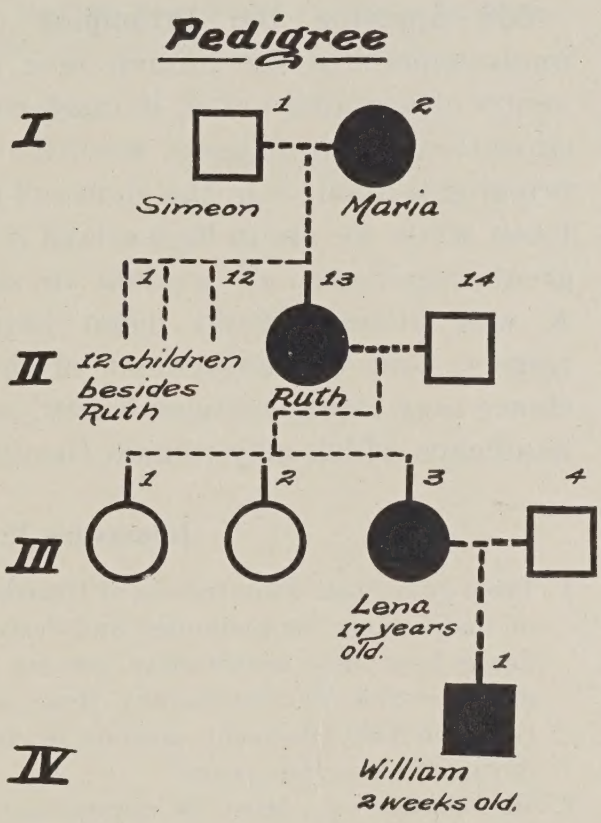


FIG. 266.—Four generations in one almshouse at one time, at Yaphank, Suffolk Co., N. Y.—July 27, 1917. A lack of ability to successfully care for oneself in organized society is shown by this family group to be heritable. This mental trait is but one of many which follow Mendel's laws as precisely as do heritable physical defects. (*Courtesy, Eugenics Record Office, L. I., N. Y.*)

524. The father of the Kallikak family was normal. The mother was a feeble-minded girl. More than one-half of their descendants were feeble-minded. Many of the others were drunkards, epileptics, and immoral persons. Later, from the same normal father and a normal mother, the descendants were all normal. As a group, these latter were industrious and respectable members of society.

525. Johnathan Edwards, a famous New England preacher and a president of Princeton University, married a woman of equally strong character. Of his descendants, there have been 11 college presidents, nearly 300 college graduates, 100 clergymen, 60 physicians, 30 judges, nearly 100 lawyers, and 75 army and navy officers.

526. Applying the Principles of Heredity.—How is this improvement in the human race possible? Like all improvements of any real value, it must come slowly and as a result of education and intelligent, scientific effort. One of the means of bringing it about is in the choice of the person whom one marries. Even while we are in high school it is not too early to realize the great importance of wisdom in selecting one's mate for life. A wise choice should mean happiness, responsibility, love, respect, and the enjoyment of healthy children. An unwise choice may mean sickness, worry, sorrow and children born with handicaps which may remain throughout life.

Interesting Projects

1. From your State Department of Health, find out the location and number of institutions for epileptics and feeble-minded persons in your state. Learn how these unfortunate persons are cared for, and how the funds are provided for maintaining these institutions. Has the number of such mentally deficient persons in your state increased or decreased during the past ten years?
2. In a similar way, learn the approximate number of persons in your state now committed to insane hospitals. Is this number greater or less than it was twenty-five years ago? Is the difference due to a natural increase in population, to more careful medical supervision, or to both causes?
3. Ask your family physician what he thinks about the practical value of applied eugenics. Find out whether he believes it possible to extend the restrictions now imposed to keep such feeble-minded, inebriate, or criminally dangerous individuals entirely restricted from mingling with society. What are the reasons for his answer?

Review

1. What family, described in this chapter, shows that strength of character and intellect are sure to produce leaders in society?

2. Why should epileptic, insane and feeble-minded persons be supported by the state and denied the right to marry?
3. How does the study of the Kallikak family show that the laws of heredity may apply to human beings?
4. In what ways have the descendants of Max Jukes been very different people from the descendants of Johnathan Edwards? To what do you attribute these differences?
5. What family, described in this chapter, best shows us that mental and moral delinquency, as well as criminal tendencies are heritable?

Define

descendant **epilepsy** **handicap**
eugenics

UNIT X

MAN CONTROLS CERTAIN ORGANISMS FOR THE IMPROVEMENT OF HIS OWN ENVIRONMENT

CHAPTER XXXIX

MAN MUST ORGANIZE KNOWLEDGE AND DIRECT DEVELOPMENT TOWARD DEFINITE OBJECTIVES

527. The value of a definite purpose in every well ordered life is well known. No one accomplishes anything really worth while by just wandering about, and to this general rule the scientist is no exception. His life must indeed be one of purpose if any real scientific progress is to come to our people.

528. Some Worth-while Objectives.—The remarkable achievements in medicine during the past few decades bear striking evidence of this fact. History records the horror that spread like wildfire whenever a mad dog was discovered at large, for until the great French scientist Pasteur developed the serum which protects us from hydrophobia, nearly everyone bitten by a mad dog died. Think of the intense suffering which accompanied every surgical operation before the year 1846 when Dr. W. T. G. Morton and others developed the use of ether to render the patient unconscious during the operation. Can you imagine the dread of surgical operations before the English scientist Sir Joseph Lister first sterilized his instruments before operating? The general mortality was over 50%, mostly from surgical infections. And thus in dozens of other ways has the scientist, by purposeful effort, organized knowledge toward definite objectives.

Likewise the plant and animal breeders every year are bringing forth new varieties of fruits and flowers, as well as new breeds of

domesticated animals. The wide selection of food products now on sale at the corner grocery store is available to us only because of the well directed efforts of the men who have produced these new varieties of foods.

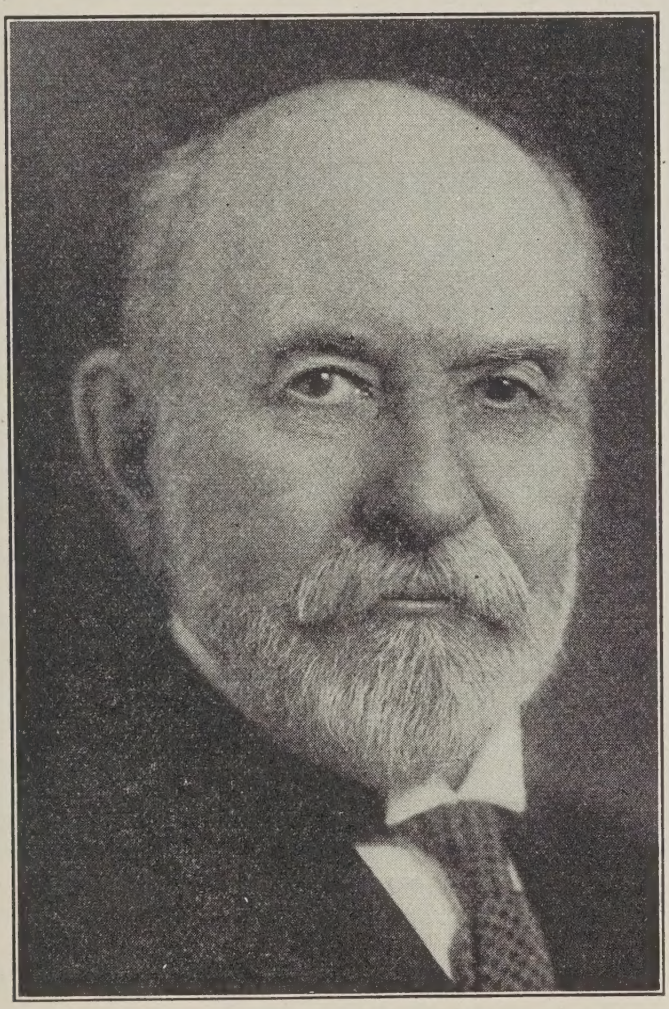


FIG. 267.—William T. Hornaday (1854–), for many years in charge of mammals at the New York Zoological Park, has long been a leader in efforts to conserve all forms of wild animal life.

529. Saving Our Natural Resources.—Only in recent years have we as a people begun to realize that our efforts must be directed toward saving our natural resources from destruction. It is extremely unfortunate that so many people have inherited a belief that these natural resources are inexhaustible. The New

England fishing fleets have grown fewer in number. A smaller number of faster boats with improved methods of fishing can supply the demand so effectively that there is now a real concern about the depletion of our supply of food fishes. Fishing has ceased to be the urgently necessary way to make a living that it was at one time. In many sections it has become a sport in which millions of dollars are invested. And there are millions

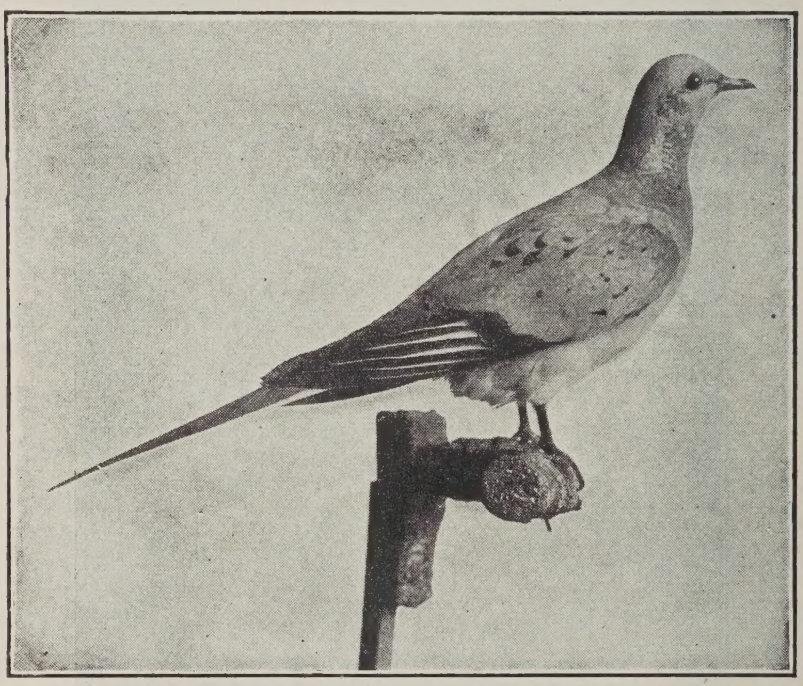


FIG. 268.—The Passenger pigeon, once so abundant, has become extinct within the memory of persons still living. (*Atwood.*)

more invested in fish hatcheries, so that the supply of game fishes may not be completely exhausted.

530. Today the walls of man's home bear evidence of his prowess with rod and gun, although such species as deer and beavers are only too often fighting for their very existence, and certain species are gone, never to return. "Although the remnant of game birds and quadrupeds now alive in the United States represents only about two per cent of the stock that existed here only fifty years ago, that remnant is sufficient to cause

the sale each year, in this country, of nearly half a million shotguns, and about 500,000,000 cartridges".[1]

531. The story of the passenger pigeon is known to nearly everyone. At one time these beautiful birds were so abundant

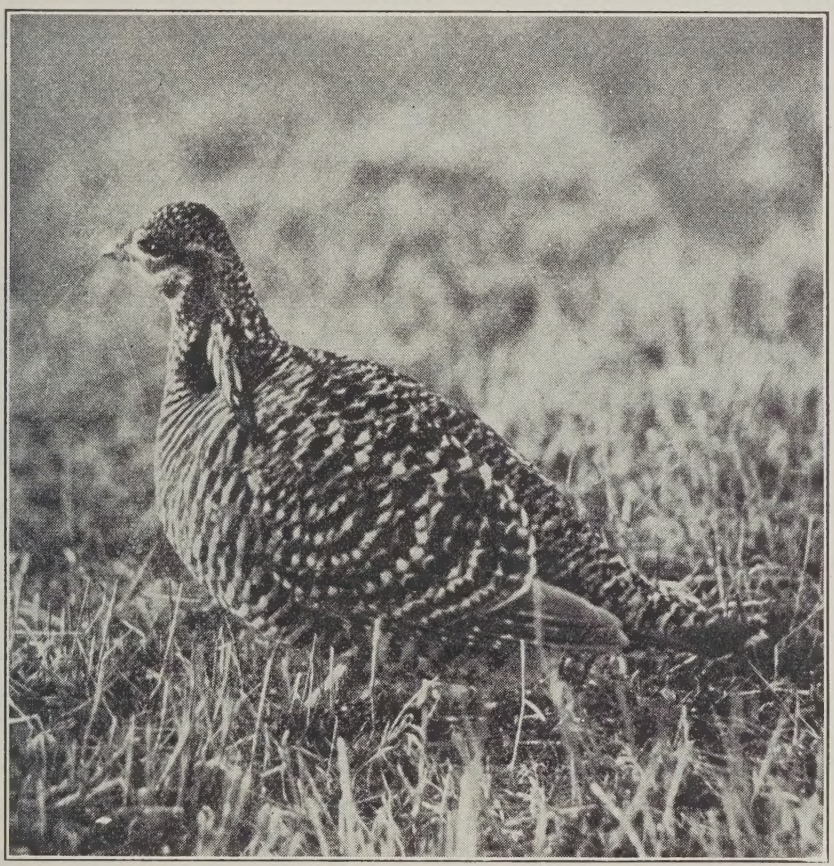


FIG. 269.—"Facing the sunset of day and the sunset of his race." This bird was the last member of his race. The heath hen became extinct in 1932. (*Photo by Dr. Alfred O. Gross.*)

that everyone knew them. The writer was once told by an old man that in his boyhood he had seen such large flocks of these pigeons fly over that "they would darken the sun". But they were easily killed for food. At night men sought out their roosting places and killed scores of them at a time. Today not a single bird of this species is alive; every one having

[1] *Wild Life Conservation in Theory and Practice*, page 19, by Dr. William T. Hornaday, Yale University Press.

perished. The year 1932 marked the extinction of the last remaining bird of the species. of heath hens, once so abundant in the eastern United States.

532. Reclamation of Waste Land.—Another objective which is claiming attention is the reclamation of large areas of waste land in the central and western parts of the United States.

FIG. 270.—Agricultural lands denuded by erosion. (*Atwood.*)

Several hundred thousand acres of otherwise valuable agricultural soil have already been wasted by erosion, especially along the Mississippi river. It is recorded that there are as many as 30,000 acres of waste land in a single county. This condition is largely due to the destruction of the forests around the headwaters of the streams which are tributaries of these rivers. With no forest floor of deep, spongy humus to take up the rainfall, the water often flows down the slopes with the force of torrents, devastating the farm lands below.

533. On the other hand, the states from Nebraska to the Pacific are held back from their normal agricultural development by lack of regulations to provide sufficient irrigation. In writing about our

186,000,000 acres of public grazing land in the west, former Secretary Wilbur of the Interior Department says: "Now is the time for conservation. Water is the key to the future of the West. . . . The great states can grow only as they find it (water), store it, preserve it. Behind the water lie the plants, preventing erosion and protecting the watersheds. What is happening? Now the plants are cut to the ground by over-grazing, burned to the roots by fire. Each rain brings thousands of tons of earth away from the hills, choking the reservoirs and tearing down the watersheds, because there has been no adopted policy of water regulations".[1] Here is a real objective which different states are solving in different ways. In Texas, half a million acres were terraced in a single year, to prevent erosion. Specific recommendations are made by the Department of Agriculture as to the extent to which grazing on certain areas should be permitted. By successful methods of hauling water, during the last fourteen years, 306,000 acres have been reclaimed and are now profitably used by livestock. Surely here is an objective which calls for organized knowledge and constructive planning.

534. Saving Our Wild Flowers.—Our best efforts need to be directed toward the conservation of our wild flowers.

Just picture, if you can, the landscape of colonial days. Every meadow and hillside was dotted here and there with a blaze of color from the native wild flowers; the woodlands abounded with a wealth of the red blossoms of wild honeysuckle and the white-flowered branches of the dogwood; below, on the ground were the patches of trailing arbutus, hepaticas (*he-pat'-ik-as*), laurel, orchids, and columbine, not to mention the hundreds of other wild flowers.

Why the great difference, today? People forgot that the supply was not inexhaustible—that to take away this year's blossoms in armfuls often meant taking away the seeds for next year's plants with **their** blossoms. And the more rare certain kinds became, the more desirable they *seemed* because they were rare.

[1] *Nature Magazine*, Feb. 1930.

535. The Wild Flower Preservation Society of America has already enlisted a small army of persons who are now as enthusiastic about enjoying and preserving these rare species of our native wild flowers as some of them once were in finding and collecting them. We should all understand that the bright colors of the native wild flowers contribute a large share in

FIG. 271.—Trailing arbutus. This beautiful spring flower should be picked very sparingly even where abundant and where permitted by law. In many sections it is fast becoming extinct. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

making up the beauty of nature and we should all feel that we, too, can have a share in preserving these flowers wherever we may find them. This of course does not apply to such species as the goldenrod, the daisy and the buttercup, for their lives are not threatened. It is the rarer species that offer us the challenge.

536. Conserving Human Resources.—We must direct our development toward still another objective, the saving of our human resources. "With power-driven machinery, steam and electric railways, telephones, the telegraph and the wireless, and finally the aeroplane, all commonplaces of our daily existence,

we are prone to forget that our grandparents lived under no such nervous strain as these inventions have brought with them, and that only three or four generations ago the high speed of modern life would have been actually inconceivable".[1]

FIG. 272.—Flowers of Mountain Laurel. The anthers are retained in little pockets in the corolla so that the stamens are bent. Only when the pistils are ripe and the flower opens, do the released stamens scatter a shower of pollen. (*Gager.*)

537. Much has been done to reduce the danger of accidents in factories. Many devices, such as blowers to keep streams of dust away from the men and women who work there, and the general conditions of industrial workers are much more sanitary.

[1] *The Conservationist*, Feb. 1920, pub. by New York State Conservation Commission.

Likewise, the hours of labor have been shortened to allow people more time for rest and relaxation. The eight-hour day has done inestimable good in permitting factory workers much greater opportunity to spend even a small part of each day out in the open than was possible a generation ago.

All over the civilized world the long hours of child labor have been shortened, and in the more progressive countries they have been done away with, for the most part. Health clinics are now instrumental in saving many lives every year, and the rapid strides taken by medical science are lengthening human life by reducing the number of infant deaths and by surgical and medical treatment of all our people.

538. Much educational work still remains to be done. We need to learn the necessity for physical and mental relaxation, and the value of more time spent out of doors in order to maintain at all times a high resistance to disease. We need also to cultivate a scientific attitude toward health and our output of energy.

If we continue along these lines of conserving our human resources and of preserving the ideals of the founders of our country, our nation will be much the stronger and America can lead the world in producing the finest types of manhood and womanhood.

Interesting Projects

1. With the help of your librarian, select one particular disease such as cancer, infantile paralysis, or diabetes, for which there is today no certain cure. Learn what steps have been taken to organize medical knowledge and research in the hope of developing a cure for this disease.
2. Look up the history of vaccination for smallpox. Who is believed to have first practiced vaccination with cowpox virus? How did the general public regard vaccination at first? What results have caused vaccination to be considered so important?

Review

1. What measures have been adopted to conserve the several species of our wild flowers which are fast disappearing?
2. Name some progressive methods already established by medical science for saving and lengthening human life.

3. What are the insurance companies doing to reduce the number of accidents in mills and factories? How can they compel the owners to thus safeguard their employees' health?
4. What measures have the several states and the Federal government taken to check the wasteful destruction of many kinds of our wild game?

Define

conservation **irrigation** **reclamation of land**
erosion

CHAPTER XL

ORGANIZED CARE OF OUR FORESTS IS NEEDED TO CONSERVE ONE OF OUR MOST IMPORTANT NATURAL RESOURCES

539. It was a rich land to which Columbus came. All the resources which have made America a great nation were as yet unspoiled and unused. From the Atlantic away across to the

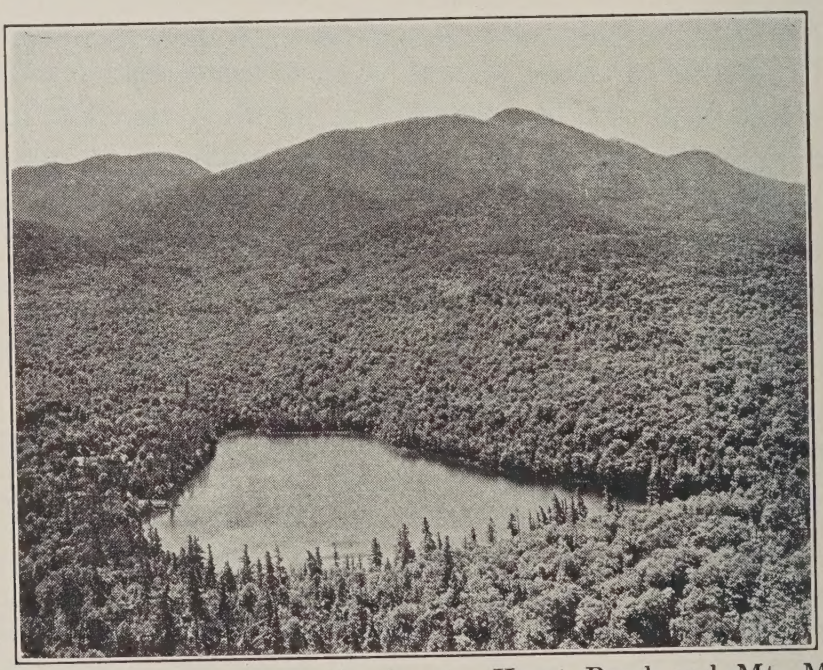


FIG. 273.—Looking out over the forests, Heart Pond and Mt. McIntyre, Adirondack Mountains, New York. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

great rolling prairies spread the forests, hundreds of thousands of acres of the finest trees that ever grew. And these could be had for the mere taking. Beyond the prairies and the desert was more wealth, way to the Pacific. This great area was the

home of a myriad of animals and plants, a veritable paradise awaiting the hand of man.

540. Man Needed Fields as Well as Trees.—The early colonists needed lumber for shelter, fuel, and protection, but their greater need was food. Fields were needed in which to raise this food, and the land had to be cleared. This was done by cutting and burning. Wood was so abundant that it was used for everything possible. As civilization advanced, the forests were cut off at an ever-increasing rate until today we are using up our timber four times faster than it is growing. Every year our lumber has to be shipped to us from greater and greater distances. We have today no large forest areas except in the West, in the Northeastern states, and in certain parts of the South. All our other large natural forests have been cut.

FIG. 274.—The forest floor, composed of dead leaves, twigs, pine needles and other decaying vegetation, serves to absorb the rainfall, and thus prevent floods.

541. Our Dependence on the Forests.—Forests are important in a number of ways. They affect our climate by giving off large amounts of water vapor into the air. Probably you have noticed that the ground in the woods is very different from the

ordinary soil in the fields. Made up of dead leaves and decayed trunks and branches, it forms a spongy covering which often extends several inches deep into the rich, black soil, full of organic matter, or humus. This soil of the forest is usually spoken of as **the forest floor.** When the rains and snows fall they remain here longer than elsewhere. The water seeps further into the ground from this forest floor and thus provides a supply for the myriad of springs and brooks which arise there. These, in turn, flow on and into the rivers.

The constant evaporation of moisture from the leaves supplies water vapor which may form into clouds and thus provide rainfall. This not only insures against long periods of drought, but it also provides a constant supply of water for domestic use, and for manufacturing purposes in our cities and towns.

542. Again, the forests aid agriculture. Aside from helping to water the lands, they prevent floods. Possibly you have read of the vast areas of land in China which have been made unfit for agriculture by the floods caused by the destruction of the forests.

"When steep, cultivated land is abandoned before its surface has been bound by vegetation, the soil that has accumulated through centuries of rock disintegration may be entirely removed by a few years' erosion. . . . On some lands gullying has proceeded so far as to render the land practically worthless."[1]

543. Forests provide a home for wild game as well as for hundreds of species of plants and other animals. Each year as the frontier of the forests is being pushed farther and farther back, the denizens of the forest must retreat also. Sportsmen and others who enjoy studying the wild game life of the forest are finding it increasingly difficult to do so, for nearly all wild creatures retreat farther into the few remaining forests to escape from their enemies, and many of them live there the year around.

544. Forests are needed for the control of floods. The headwaters of our rivers and other streams need the forest areas to supply the steady flow of water which these streams require. Have you noticed this relation between forests and floods? Our

[1] Yearbook of Agriculture, 1930, p. 282.

forests are slowly disappearing. Our spring and fall floods, with all the damage, disaster, and loss of life which attend them, occur nearly every year with increasing severity. Have you not noticed this?

In his excellent book "The School Book of Forestry," Charles Lathrop Pack writes, "One of the chief reasons for the establish-

FIG. 275.—Forests furnish streams with a steady supply of water. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

ment of the National Forests was to preserve the natural conditions favorable to stream flow. In a treeless country, the rise of the streams is a very accurate measure of the rainfall. In the regions where forests are numerous, an ordinary rain is scarcely noticed in its effect on the stream. In a denuded district no natural obstacles impede the raindrops as they patter to the

ground. The surface of the soil is usually hard. It is baked and dried out by the sun. It is not in condition to absorb or retain much of the run-off water; consequently the rain water finds little to stop it as it swirls down the slopes. In torrents it rushes down the stream beds, like sheets of water flowing down the steep roof of a house."[1] A new problem, that of flood control, has arisen in recent years and assumed such proportions that it is now a national problem. Should we not give equal consideration to reforestation—doing away with the cause of these floods?

545. The washing away of the soil takes place in those regions where the forests have been cut off and therefore cannot hold back the rains as they fall, and let the water run off slowly or else evaporate into the air. The fact that Congress appropriated $160,000 for the study of this problem shows in itself that it is serious.

"In the brown-loam belt along the Mississippi river, many counties have been found to contain 10,000, 20,000 and even 30,000 acres of land that have been ruined. Agriculture has been largely driven out of the uplands in this region by reason of destructive and unrestrained erosion."[2]

546. The Products of the Forest.—The principal forest products are lumber, firewood, and pulpwood for making paper and as material for innumerable small articles manufactured from wood. Other products are maple sugar, tar, resin, turpentine, tannic acid, wood alcohol, witch hazel, and many medicinal herbs such as quinine.

We are using up our supply of wood much faster than it is growing. "$510 was required in 1921 to purchase as much lumber—and poorer in quality—as could be bought for $100 in 1840."[3] We are using more than 8,000,000 tons of paper pulp every year and 90% of the raw materials from which this is made, is wood. Not all of this wood comes from the United

[1] *The School Book of Forestry* by Charles Lathrop Pack, published by the American Tree Association.

[2] 1930 *Yearbook of Agriculture*, page 44.

[2] *Reforestation, Report No. 28*, 68th Congress, 1st session.

States. Approximately one-half comes from foreign countries in the form of pulpwood, manufactured pulp, or finished paper. Nearly one-third of it is imported from Canada. A good share of our forests are some distance away from the industrial centers where the lumber is used. This brings an added burden on the people in the form of many millions of dollars for transporting this lumber, wood pulp, and other forms of wood. In a single

FIG. 276.—In many logging operations tractors are used to haul the logs out of the woods. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

year the freight on these products has amounted to as much as $250,000,000.

547. Enemies of the Forest.—In speaking of man as an enemy of the forest we do not mean *all* men. The Indians of America realized the value of the forest if for no other reason than that it supplied them with game. Nor do we refer to the intelligent peoples of western Europe who have improved the forests there and made them more valuable than they were under the natural conditions. But in this country of ours the rank and file of our people have had little regard for preserving our forests. By lack of foresight and by the careless use of them they have destroyed vast quantities of the original forest areas. An idea of the destruction of our forests may be gained when we consider

that of our original 822,000,000 acres of virgin forest, only 138,000,000 acres remain. Careless lumbering methods, the wasting of usable parts of trees where only the trunk is used, the needless destruction of young trees, the use of portable sawmills which take out the half-grown trees along with those ready to be cut, carelessness in allowing forest fires to lay waste whole areas of valuable standing timber, and a slow awakening to the need of reforestation are responsible for many of our forest losses.

548. *Fire.*—Most of our forest fires are caused by the careless throwing away of burning matches, cigar and cigarette stubs,

FIG. 277.—The forest fire, especially if a large one, is a thing to be feared. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

and by sparks from railroad locomotives. "In California alone, the fire demon takes a toll of more than a million dollars every year from her fields and forests."[1] The Clarke-McNary law which was passed in 1924, authorized a Federal appropriation of $2,500,000 to protect our forest lands from forest fires. Much

[1] *Yearbook of Agriculture*, 1930, p. 276.

constructive work and valuable organization has resulted from this measure.

FIG. 278.—After the forest fire has passed. (*Courtesy, American Forests, the magazine of The American Forestry Association.*)

549. *Insects.*—Insects cause a total loss of more than $100,000,000 annually to the forest products of the United States. A great many species of destructive insects are constantly at work in the forests injuring or killing live trees and even attacking dead timber.

Some insects eat the leaves and frequently kill the trees. Other insects work under the bark and bore into, or else girdle the trees, causing their death in that way. The solution of this problem lies, to a great degree, with the forest rangers whose duty it is, when such injuries have been discovered, to see that proper measures are taken to control these enemies. One method is to find and introduce parasites, usually from foreign countries,

which will destroy these insect pests. Another method is to destroy the infested trees to prevent the spread of the insects. Still another way is the spraying of areas infested by such parasites as the brown-tail and gypsy moths.

550. *Fungi.*—Fungi, as the term is here used, are parasitic plants that either weaken or kill forest trees. One such fungus is the well-known chestnut blight. The tiny seed-like spores by which the parasite breeds are blown by the wind onto the bark of healthy trees, and thus the disease is spread. Foresters try to locate and dispose of all fungus-infected trees, so that the spread of the disease may be checked. When the source of the parasite is traced to nursery stock or to forest products of any kind coming here from another country, a quarantine is immediately placed upon importing such stock or products from that country. From time to time there appear trees which are not affected by one of these diseases. Such trees are said to be immune to that disease. One of the hopes of the forester is that in time we may find and establish many varieties of our more valuable species of trees which will prove to be immune to fungus attacks.

551. Forestry as a Profession.—There is perhaps no life work which offers to the right type of man so much of satisfaction and enjoyment of life, day by day, as that of the forester. We said "the right type of man," for to others the work would be drudgery and unless one possesses the qualifications mentioned below, he should not even consider this work. First, he must love the great out-of-doors; love to work in it in cloudy weather as well as in sunshine. He must be at home among the trees and get to know them as his neighbors, and the forest creatures as his friends, for he and they are spending their lives there together.

552. His must be a spirit of service, for he is managing his forest in such a way as to best serve the purposes of its owners and his fellowmen in general. He must know trees, their characteristics, the conditions under which different species grow best, their enemies and how to combat them. He must know

something about soil, about surveying, and about measuring and scaling lumber. He should be able to get along with folks, for he will want to be on friendly terms with the lumber companies which may be cutting in his forest, with nearby farmers, sheep raisers and cattle owners, homesteaders and sporting camp operators. For if he does gain a reputation as being square, intelligent, and sincere, he will get their aid when fires spring up

FIG. 279.—The home of a forest ranger. (*Corwin and Corwin.*)

in the forest; and what is more, their respect and cooperation will keep many a fire from ever getting started.

The United States Forest Service as well as those of the various states is made up of a fine body of men, unselfish as to their personal gains, and very loyal to the service. They have the long-range point of view which every forester must have, for few of the men ever see the reaping from what they sow in "the city of trees".

553. Our National Forests.—These include more than one hundred and forty separate bodies of timber covering over 159,000,000 acres. For efficiency in management these are divided into nine districts which cover areas scattered over the whole United States, more especially in the mountainous regions

of the west where land values are low and the areas are particularly suited for raising timber. "Fire fighting takes precedence over all other work in the National Forests. Lookout stations are established on high points to watch for signs of fire. Airplanes are used on fire patrol over great areas of forest. . . . Every year the National Forests are being improved and made more accessible by the building of permanent roads, trails and

FIG. 280.—A forester at work. (*Photo by U. S. Forest Service.*)

telephone lines. . . . Communication throughout the National Forests is had by the use of the telephone and the radio or wireless telephone. . . . Over 25,000 miles of roads and 35,000 miles of trails have already been constructed in these forests. . . . Over a billion feet of timber, valued at more than $3,000,000, is sold annually from the National Forests . . . More than 9,500,000 head of livestock are pastured annually under permit in the Federal forests. In addition, some 4,000,000 to 6,000,000 calves and lambs are grazed free of charge."[1] During 1928 more than 82,000,000 feet of timber was allowed under certain restrictions to be cut from these forests, free. In addition to all this, many thousands of our people spend their vacations in these forests.

554. Control of Forest Fires.—As has been stated before, the control of the forest fire is the first consideration of the forester.

[1] *The School Book of Forestry*, Pack, pages 81, 82, 84, American Tree Association.

On the average, about ten million acres of forest lands are burned over every year by these fires. According to the Department of Agriculture, the losses to the Government during the year 1910, in which there were the greatest number, were more than $26,000,000.

Aside from the ever-present factor of carelessness which in the Eastern states is responsible for ninety-nine per cent of these fires, the three factors which produce unfavorable weather conditions are (1) long periods of severe drought when the forest gets very dry and fires are easily started; (2) much lightning, especially in the West; and (3) violent, hot winds.

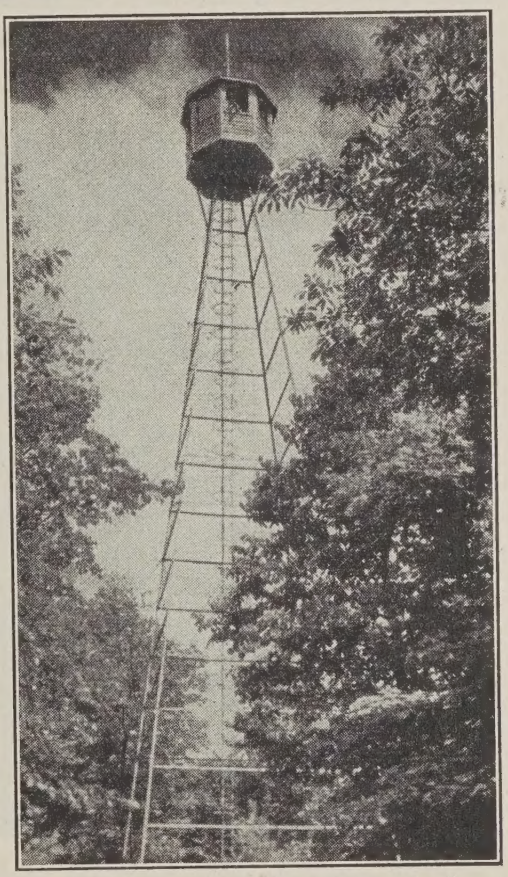


FIG. 281.—From forest fire lookout stations such as this one, men are constantly on guard, to discover forest fires as soon as they start, and to get crews of men to the fires before they get beyond control. (*Ontario Highway Department photo.*)

555. Since the passage of the Clarke-McNary law, which made available the sum of $2,500,000 annually for the organization and operation of constructive measures for protecting the forests of the United States, this work of preventing and fighting forest fires has reached a high degree of efficiency. There will always be forest fires as long as there are forests, but their prevention and control are now being handled in the following ways:

556. Nearly every state in the Union now maintains a forest lookout system which provides for lookout men constantly on guard throughout the day during those months when there is danger of fires. These guards are stationed in towers located on the tops of

the highest mountains where they continually watch the wide area spread out before them on all sides. They have a telephone, a large table map, a range finder, binoculars, and the other necessary equipment. The instant that a smoke appears they get in touch with the nearest lumber camp, railroad crew, settlement, sporting camp, or other group of men and summon aid, directing them to the danger spot. It is the first few minutes that count the most. Ordinarily a small fire is not difficult to put out, while a large forest fire is tremendously difficult to fight, and dangerous even to the lives of the very men who are fighting it.

FIG. 282.—One of the several kinds of forest fire warnings.

557. In some of the larger forests in the west, an airplane patrol is maintained over the forests because of the vast area which a plane can cover and because of its ability to cruise about over rough and remote mountain areas immediately after the severe and frequently rainless electrical storms which cause a large number of forest fires in the mountain regions of the west. Many fires not easily seen by the ground crews are thus quickly discovered and reported by the planes. Each year between 5,000 and 6,000 fires occur in our National forests. Small fires are put out by beating them with green boughs or wet burlap; sometimes by ditching around them or shoveling sand upon them. This does not apply to the larger ones. In experienced hands the method known as "back-firing" is often a great help. This consists of starting a small fire against the wind. It is controlled, and when the main fire reaches the burned area it goes out for lack of fuel. Only those who are experienced should attempt

back-firing as they may lose control of it, or the fire may be started too soon, or the direction of the wind may change. Thus the new fire may in itself become a menace.

558. Much educational work is being done by the use of educational fire posters, such as the one on page 388, by public lectures, and by enlisting public interest and cooperation generally. Much valuable work is also done along this line in the schools. When all of our people realize the truth expressed in one of the fire posters, "Everybody loses, when timber burns," we shall be a long way toward preventing the 70 to 75 per cent of all forest fires, termed as "man-caused fires."

559. Reforestation.—Reforestation or the planting and growing of new forests is necessary mainly for three reasons: (1) the great shortage of wood, (2) the necessity for the control of floods, and (3) the prevention of soil erosion.

During the past few years a general awakening has taken place among our more progressive people looking toward extensive reforestation, and today in many parts of this country extensive forest planting is being done. For example, the Forest Service in 1930 planted 21,000 acres in the national forests, and the various states are doing similar work along this line, but reforestation is not confined to planting. The measure of a good forester is his ability to get reforestation of the valuable species of trees by natural seeding. Planting is required only where the forests have been badly mistreated.

560. Forest Work of the Civilian Conservation Corps.—A great amount of work in our National forests as well as state parks and some of our island possessions has already been accomplished by the 272 camps of the Civilian Conservation Corps.

Some idea of the work already completed by these camps in the forests may be gained from the following data[1] as shown on p. 390.

561. The Recognition of Trees.—There is a certain kind of satisfaction in knowing the common species of trees that grow

[1] *Emergency Conservation Work report*, March 31, 1934. The data given here shows but a part of the work completed at the time this report was issued.

Type of work	Completed work
Fire telephone lines	15,241 miles
Fire breaks	18,531 miles
Reduction of fire hazards	542,659 acres
Trail and roadside clearing, fire prevention	15,617 miles
Lookout houses	274
Lookout towers	355
Forest stand improvement	953,318 acres
Road and trail construction, all kinds	32,221 miles
Pipe line construction	618,757 feet
Wells and water holes dug	1,340
Planting	98,592 acres
Range revegetation	6,939 acres
Seed collection (*a*) conifers (cones)	16,996 bushels
(*b*) hardwoods and other	259,591 pounds
Insect pest control (*a*) tree	1,666,637 acres
(*b*) other	203,479 acres
Tree and plant disease control	2,757,419 acres
Erosion control—dams	420,633
ditches, drainage, etc	53,614 linear yards
Ponds for birds and fishes	1,170
Flood control, various types	2,542,560 cubic yards
Landing fields, airplanes	1,887 acres
Mosquito control (ditching and staking)	482,709 linear yards

around our homes. The trees which have grown there form a part of the surroundings of our childhood. Perhaps as children we played under a certain old willow or some other tree. Here was our swing, and the games and the hours spent there are somehow associated with that particular tree. To the boys and girls who live in the country, a certain old sugar maple tree often, in later years, means a great deal for reasons of association only. Should not we all, therefore, get acquainted with the tree or the group of trees that forms a definite part of our home environment?

As an aid in starting to learn these, we are giving you here a rather brief description of a half dozen of the more common ones. Of course in some sections of the country you will find certain other species more common, but by writing to your State

Forester, addressed at the Capitol of your State you can usually get free booklets and printed descriptions of those kinds of trees which do grow near your home.

562. The Sugar Maple, also called **rock maple** or **hard maple,** grows to be a large tree from fifty to eighty or ninety feet in height. In young trees the bark is dark gray with a slight shade of buff. The branches run upward in young trees and reach out horizontally in the older ones. The young trees have close, firm bark. The thicker bark of the older trees is broken and furrowed because the area of their outer surfaces is greater than that of the inner surfaces and the growth of the outer surface has not been able to keep up with the growth inside. The two wings attached to the seeds, are broad and are usually from one to one and a half inches long. The small branches also develop in pairs on opposite sides of the main branches. This species is easily distinguished from the other maples by its narrow brown buds which are sharp pointed. The fruit clusters also develop from terminal buds. This is not true in the red and the silver maple.

FIG. 283.—Rock or sugar maple, the source of our maple syrup. (*Ontario Highway Department photo.*)

563. The American or White Elm is a tall, graceful tree, often reaching a height of sixty to one hundred feet. It is one of the commonest forms of shade trees along many streets. The trunk has a diameter from one to five feet according to its age. The trunk often divides into several limbs which spread out as they grow upward and form a round-topped head with graceful, drooping branches. The leaves are alternate, from two to five inches long and have coarsely double-toothed margins. The bark on the trunk is divided by irregular grooves into broad ridges, and

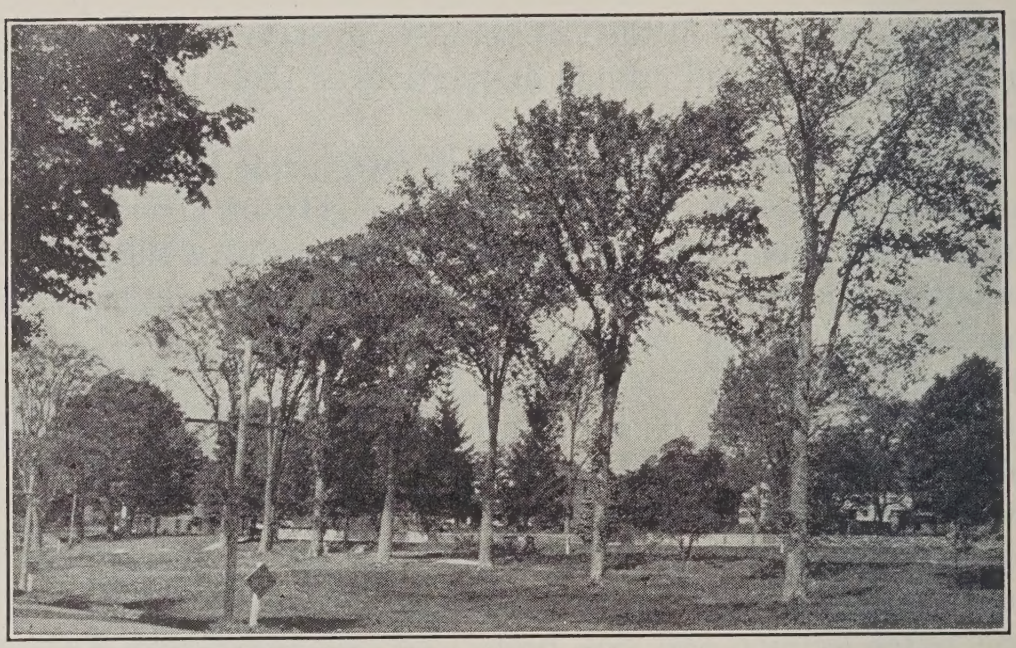


FIG. 284.—Roadside elms add dignity and charm to many of our villages.

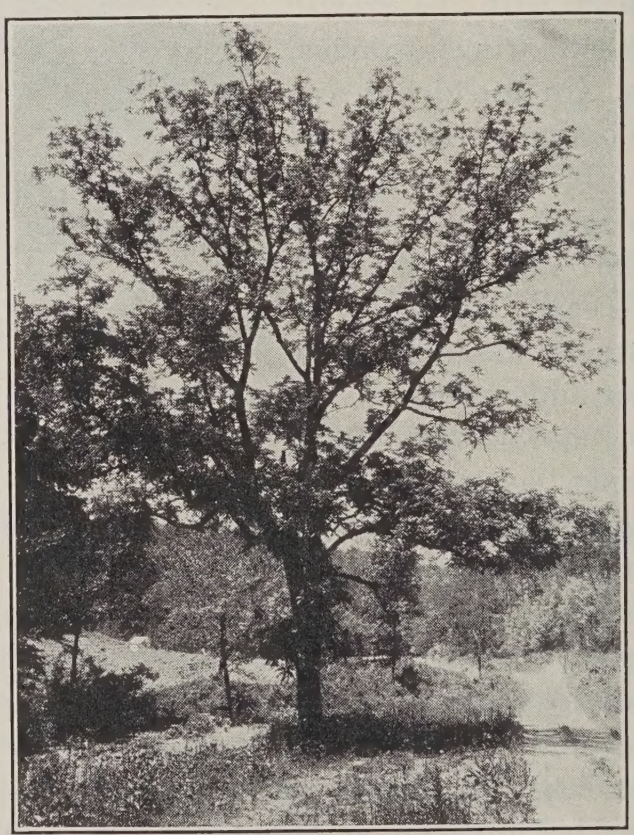


FIG. 285.—The black walnut is one of our valuable trees. The wood is much used for fine furniture of all kinds. (*Courtesy of U. S. Forest Service.*)

is of an ashy gray color. The twigs are slender and light reddish brown often shaded with yellow. The fruit contains a small seed and has two oval wings by means of which it is blown about when ripe, usually in the latter part of May before the leaves are fully grown.

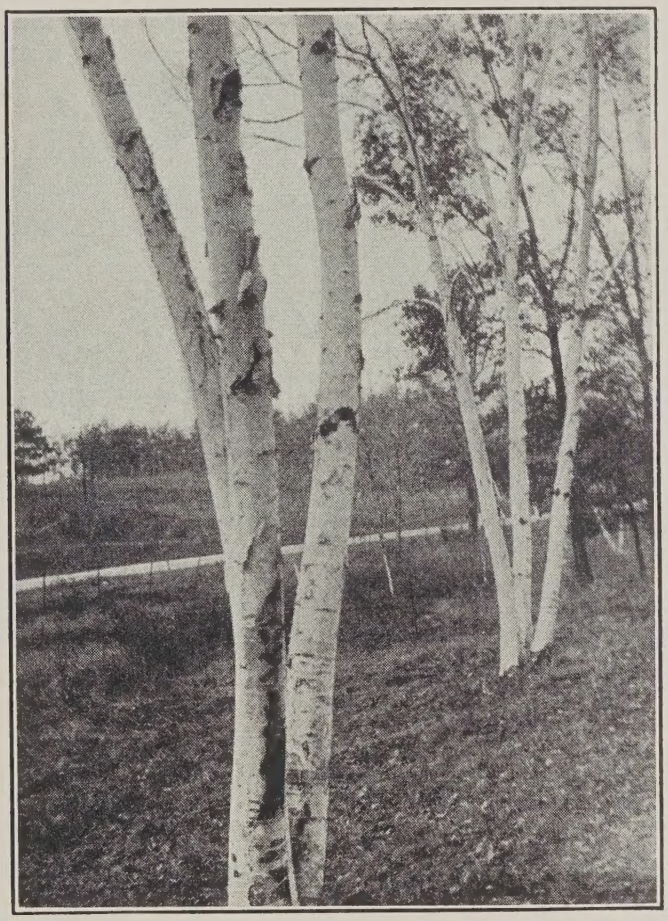


FIG. 286.—White birch trees. The Indians used the bark of the white birch for their canoes.

Were it not for the elm-leaf beetle which destroys large numbers of elms every year, these beautiful roadside trees would be planted much more extensively.

564. The Black Walnut is another valuable tree, but each year it is becoming more rare because of the growing popularity of walnut furniture. Its height usually ranges from fifty to seventy-five feet, although in the Ohio valley specimens are found

which are twice as tall. The bark is thick and dark-colored. The twigs are stout and the fruit is either round or oval. The husk varies from 1½ to 3½ inches in diameter and contains the dark brown, roundish nut. The wood of the black walnut is heavy, and hard. It is known the world over for its beauty, when

FIG. 287.—The oak tree is noted for its sturdiness. Its lumber has great value for furniture and the interior trim of buildings.

finished and polished. It is used principally for fine furniture and gunstocks.

565. The White Birch, also known as **canoe** or **paper birch** is a beautiful tree which you probably have seen. Its name is derived from the color of its tightly wound white bark. In older trees this bark gets torn and loosened, often hanging in strips from the very old trees. This tree branches often, and fairly low. The fruit is a cylindrical, smooth catkin from ¾ to 1½ inches long. This was the tree from which the Indians got the bark for their canoes. It is also used today for making small baskets, picture frames, and other novelties; because the bark on the trunk and larger branches is chalky white, and peels very easily. This fact has led careless persons to peel the bark

off many of these trees needlessly, and thus destroy their natural beauty.

566. The White Oak with its broad, sweeping branches is a tree you should know. Its bark is light gray and flaky. In the larger trees it is furrowed and ridged and often nearly two inches thick. Like all the oaks it bears the familiar acorn. Sometimes the broad expanse of the branches is twice as great as the height of the tree. The wood is close-grained and very strong; hence it is much in demand for the interior finish of houses and for furniture of all kinds. When properly sawed and dressed it has a beautiful finish and is the most valuable member of the whole oak family.

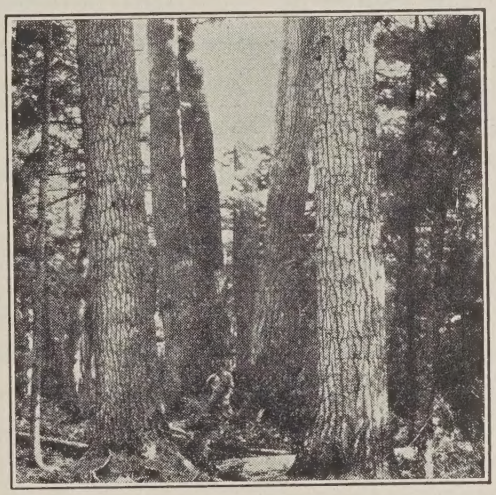


FIG. 288.—The white pine. (*Ontario Highway Department photo.*)

567. The White Pine.—Somehow we associate the pine and its thick, dark green boughs, with the forest, for it is a stately tree and its fragrant odor seems to breathe out the quietness and restful peace of the woods. Like all the evergreens it has leaves which are very narrow and pointed. These leaves are sometimes called "needles," and as the name "evergreen" implies, they do not fall off at the approach of winter, but remain on throughout the year. Five needles in every cluster—this is perhaps the easiest way to distinguish the white pine from the other members of its family.

Just to illustrate how much certain trees can mean to you later in life, let me say that, even now, after being away from them thirty years, the writer recalls very clearly a certain Maine hillside covered with that forest of pine. The foliage was always dark green there and it was cool and shady and quiet. Somehow the arbutus that grew there, and the crows that nested in those same pines are associated with the very trees themselves. Do you now understand how much certain trees can come to mean

to you, years later, if you only get acquainted with them now?

568. Federal and State Protection of Forests.—Every year as the people of the different states realize more fully how valuable the forests are and how fast these forests are disappearing, they plan and work out ways to protect them.

Besides what has already been done, many other problems remain. In such cases the United States Department of Agriculture stands ready to aid in remedying the trouble if it is serious. The state agricultural colleges and the organization headed by the state forester are likewise ready to give valuable assistance to the farmer and the owner of the private forest. The state and national forests are already organized to check outbreaks of various kinds, and are doing so, effectively. Much work is also being done along educational lines, by means of public lectures, newspaper publicity, and posters to prevent careless use of the forests by woodsmen, hunters, and campers. Some of the posters appeal to our sportsmanship in words like these: "Let's stamp out Forest Fires; they destroy the Recreation Grounds and Game". "Leave a Green Camp and a Clean Record". "Save the Trees; You May Want to Come Back".

569. Injury from grazing livestock that often eats the twigs or gnaws the bark from trees and bushes is also guarded against. State laws usually permit the owner of the private forest to kill such animals as porcupines, deer, and beavers where it can be proved that they are damaging forest trees. Care in logging is urged. Some states as well as the federal service maintain seed-collecting and extracting operations which furnish seed at reduced prices for reforesting.

570. Forestry Abroad.—Probably in Germany can be found the outstanding example of forestry in foreign countries. Rigid restrictions have been practiced for years because their timber shortage was felt long before ours was noticed. Sweden and France are also among the most progressive countries in forestry practice. Two-thirds of the forests in Switzerland are municipally-owned. New Zealand and Switzerland have passed rigid

laws restricting the exporting of their lumber. Norway regulates the extent of cutting by individuals, while Russia is now requiring that young trees be planted to replace those cut. Austria and Australia now have constructive forestry programs, and England has recently passed laws looking toward extensive reforestation. These nations realize, as we are beginning to, that a forest gone is but slowly replaced, and that such an important natural resource needs to be guarded.

Interesting Projects

1. How many articles made wholly or partly from wood can you see from the place where you are now sitting? Make a list of them. If the supply of wood continues to decrease, what will be the effect upon the price of such articles as those you have listed?
2. From your library books on forestry read about the various measures used to prevent and check forest fires. Make a report to your class describing the measures which you consider most effective.
3. Write your State forester for free literature on the public forests in your state. Visit one of these forests nearest your home and learn first-hand about the results of thinning, transplanting, building of forest roads and other forestry practices. Find out also from your State forester whether your state is able to furnish its own supply of lumber.

Review

1. Of our original virgin forests what part is left today?
2. In what ways do forests aid agriculture?
3. How many thousand acres have been planted to forest trees by the men in the C.C.C. camps up to March 31, 1934?
4. Name four of the principal enemies of the forest.
5. What objectives lie behind our system of national forests?
6. Explain how a privately owned timber property may be managed so as to insure a steady supply of marketable lumber.

Define

catkin
foliage
forest lookout station
humus
immune
pulpwood
reforestation
resin
turpentine

UNIT XI

A KNOWLEDGE OF BIOLOGY IS VALUABLE FOR MAINTAINING HEALTH

CHAPTER XLI

THE SKELETON OFTEN ASSISTS THE MUSCLES IN THE PERFORMANCE OF THEIR FUNCTIONS

571. One of the most important functions of the human body is the ability to move about. It is impossible to imagine what our lives would be like if we could not do this. And yet our ability to move from place to place, or even to move the parts of our bodies such as the tongue or the hands, depends upon our muscular system. And when we move from one place to another we depend upon our skeleton as well as upon our muscles. We need, therefore, to study these two important parts of our bodies.

"Everybody ought to be interested in the skeleton" says Dr. Herbert E. Walter, "because everybody has a skeleton all his own". It is made up of more than two hundred bones, each one of them having a definite work to do. The skeleton, as a whole, does two very important things for us: it offers support by its rigid framework, and it protects the delicate organs within, such as the brain and heart.

572. Skeletal Structure.—The central part of the skeleton (that which forms the main axis of the body) is known as the **axial skeleton.** It consists of the skull, the thirty-three vertebrae, the ribs, and the sternum. The remainder of the skeleton, is concerned with the appendages and so, is known as the **appendicular** (*ap en dik' u-lar*) **skeleton.** It consists of the bones

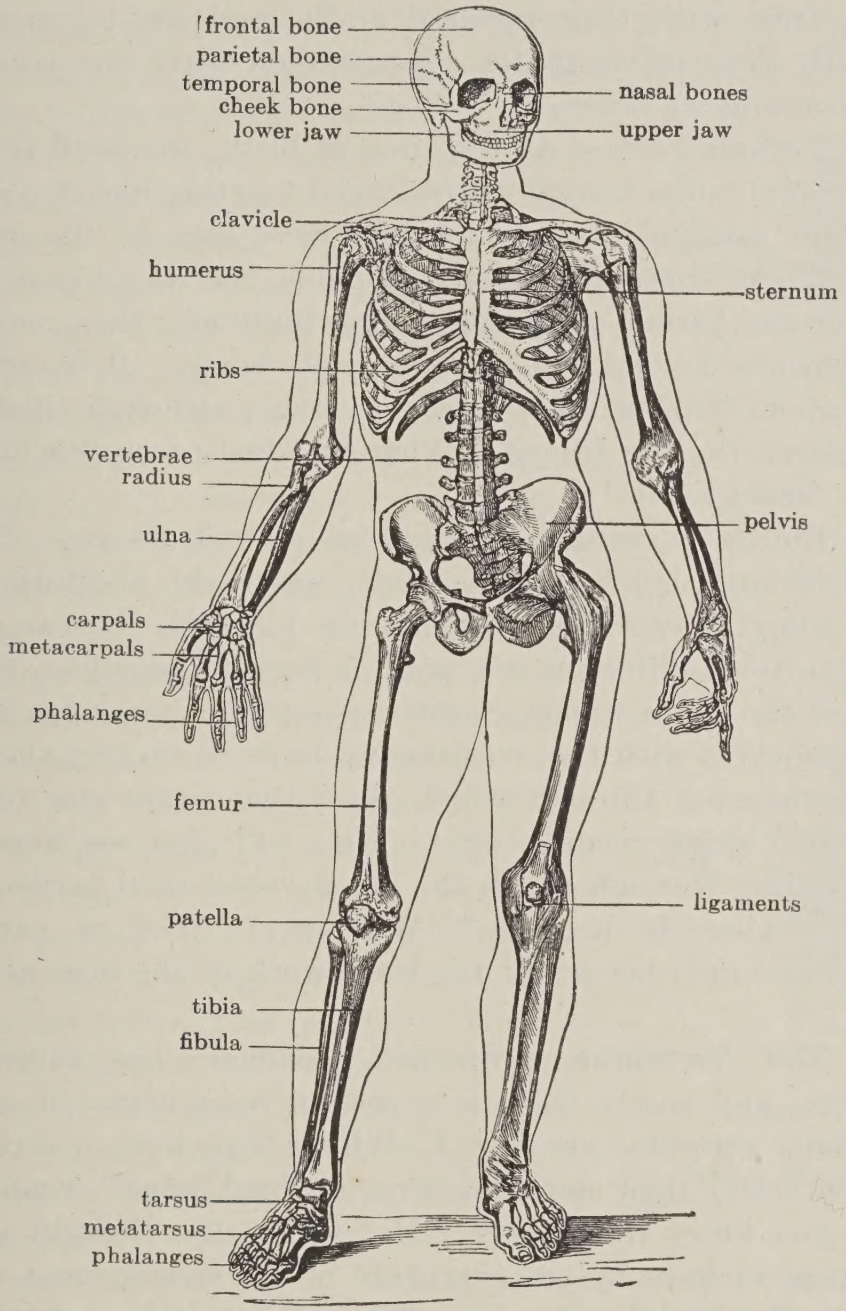


FIG. 289.—The human skeleton. (*Holmes.*)

of the appendages and their girdles; in other words, the bones of the arms with their pectoral girdle, and the bones of the legs with their pelvic girdle. You should learn the names of these arm and leg bones.

573. *Various Parts.*—At the time of birth, the skull is made up of several bones carefully dove-tailed together like the corners of certain wooden boxes which you have seen at the grocery store. These bones are slightly movable, but as we grow older they become harder, more lime being built into them, and the skull becomes a solid case of immovable bones. It is not very thick, about half an inch on the average, although thicker in some places than in others. What an ideal protection for the delicate brain within!

574. But let us examine the skull for other structures. Notice the fairly large holes on either side, where the auditory canal allows sound waves from the outside to reach the ear drum, thence to the auditory nerve, and, as nervous impulses, to that region of the brain which records the sense of hearing. Notice the eye sockets with the overhanging brow to protect the eyes, and the opening through which the optic nerves run to that brain area which records sight. You will also see numerous tiny openings through which the blood vessels and nerves pass. And the nose—is it bony? Why not? Why is cartilage (gristle) so much better for the framework of the nose and the ears?

575. The Vertebrae.—"Spools", someone has called the vertebrae, and surely there is a certain resemblance in shape. How many vertebrae are there? Why is this chain of vertebrae so much better than one solid bone, a "back bone", would be? Surely you know the answer. Have you ever thought of the advantage we gain by the curvature of the arrangement of the bones in the back? (See Fig. 290.) What feeling should we experience after a broad jump, if our backs were rigid? We sometimes hear about the "seven cervical vertebrae". The word cervical means "pertaining to the neck," and these first seven bones make up the framework of the neck. The upper

one is the **atlas.** Look up the Atlas of mythology and see what he held up, according to that old myth. Then you will agree that atlas is a good name for the first of the cervical vertebrae, the one which supports the skull.

576. If you have closely examined a skeleton, you have probably noticed that all these vertebrae have large holes through them. When arranged in a series, these holes form the **neural canal** in which the spinal cord—a bundle of nerves—comes down from the brain. These delicate nerves surely need good protection. If you have ever bumped your "funny bone" or suffered from an exposed nerve of a tooth, you know how delicate and sensitive nerves are. We can thus appreciate how necessary is the excellent protection offered by the vertebrae to the bundle of nerves within.

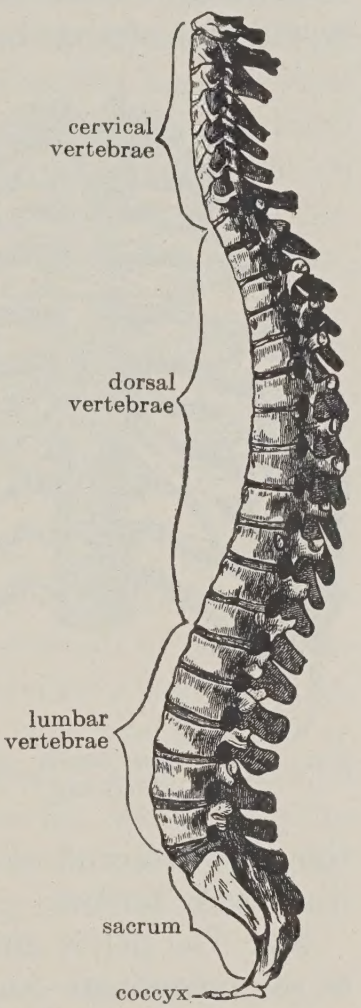


FIG. 290.—Side view of the human spinal column. (*Holmes.*)

577. The Ribs and Sternum.—There are twelve pairs of curved ribs—the same number in both sexes. Each rib is about a half inch wide and a quarter inch thick. The eight upper pairs, which are called **typical ribs,** extend all the way around, being attached loosely in front to the breast bone or sternum. The ninth and tenth pairs are attached to the sternum by long strips of cartilage. The lower pairs, which are shorter, extend only part of the way around to the front. All the ribs are attached dorsally to the vertebrae but are slightly movable there. You will learn later how important it is that the ribs be slightly movable so that air can be drawn in when we breathe. The thoracic or chest cavity contains very important organs, the heart and the lungs, which need the protection of bones.

Can you tell why the bony framework of the chest needs to be distensible?

578. The Girdles.—How are the appendages dependent upon the girdles? If the arms and legs were attached to the vertebrae, would this arrangement permit the freedom of motion that we now have?

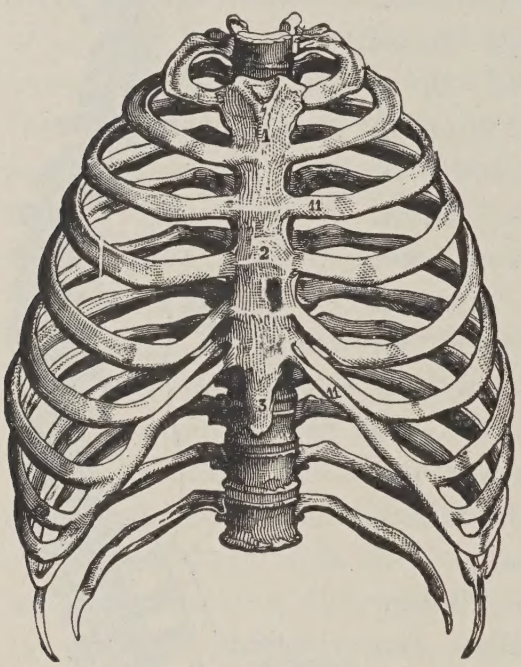


FIG. 291.—The bones of the chest. (*Bundy.*)

579. The **pectoral girdle** consists of two parts: the broad **scapular** (*skăp'ŭ lăr*), or shoulder blade, which affords plenty of surface for the attachment of the shoulder and arm muscles; and the **clavicle** (*klăv'ĭ k'l*) or collar bone, which acts as a sort of brace. If you feel at the front of your shoulder you will locate this bone. How large is it? To what is it probably attached in front? You would do well to look at a skeleton or at the accompanying diagram of one to make sure of the answer to this question, and at the same time to see why the collar bone is so easily broken.

580. The **pelvic girdle,** or hip girdle, is made up principally of the **innominate** (*in-nom'-in-āt*) (without a name) bone which is fused to the **sacrum** (*sā'krum*). This latter bone is composed of fused pelvic vertebrae and is thus very strong. Thus the girdle forms a sort of large cup which not only supports the abdominal organs but in addition offers large, strong sockets for the upper, round end of the long leg bones which support so much of our weight. It also offers great freedom of motion which is necessary in all forms of exercise, especially that of running.

581. The Arm and Leg Bones.—Someone has said that the long bone of the upper arm is called the "humerus" because it is

just above the "funny bone". The latter is a partly exposed nerve. The upper end of the humerus is united to the shoulder by a ball-and-socket joint. Why does this type of joint serve better than would a hinge joint for the work that it has to do?

582. Just below the elbow are the **radius** (*rā'-de-us*)—located in front—and the **ulna**—at the back. Notice that here we need two bones so that we can turn our hands over by twisting these bones slightly around each other. They are attached by hinge joints to the humerus above and to the carpals at the wrist. The metacarpals (*met-ah-kar'-pelz*) are the bones of the hands; the phalanges (*fā lăn'jēz*) are the finger bones.

In the leg the **femur** is analogous (*an-al'-o-gus*) (functions the same) to the humerus; likewise, the **tibia** and the **fibula** are analogous to the radius and the ulna. Why need there be so many joints in the tarsals, metatarsals (*met-ah-tar'-salz*) and phalanges?

583. When next you see a motion picture or play in which a skeleton is used to produce momentary fear or an atmosphere of mystery, it will be interesting for you, as a student of biology, to notice the presence of false parts that the theatrical skeleton may possess. Often the sternum or the knee caps are missing, or there may be too many ribs. And so it goes. Such situations are interesting ones for the biologist, and for the rest of your life you may be interested in the structure of the **parts** of every skeleton that you see. No longer is it a thing of dread and horror, but rather, a wonderful mechanism.

584. The Structure of Bones.—Cartilage is the forerunner of bone. In amphioxus, a very simple vertebrate, the cartilaginous (*kar-til-aj'-in-us*) notochord is permanent, whereas in the higher forms it is later replaced by bone. You may have seen the cartilage at the front part of the breastbone in a chicken. This cartilage becomes true bone in the fowl. Or perhaps you may have noticed the soft spot, known as the fontanelle (little fountain), on the top of a baby's head. This cartilage always ossifies later into bone, as it also does in many other parts of the body. These facts explain why children can fall and usually

escape serious injury, while an elderly person is less fortunate, a fall often proving most serious in its consequences. Examination of a bone, such as the femur, shows a long shaft of hard bony tissue, and a central hollow portion containing marrow. A spongy tissue caps the ends, and cartilage forms the coating at the joint.

585. Most of the bones are connected by joints. A joint is defined in biology as **the meeting place of two or more bones.** They are of three kinds: **movable** joints, such as the ball and socket joint at the shoulder; **immovable** joints, such as those of the skull of adults; and **mixed** or semi-movable joints, such as those between the vertebrae, where motion is rather limited.

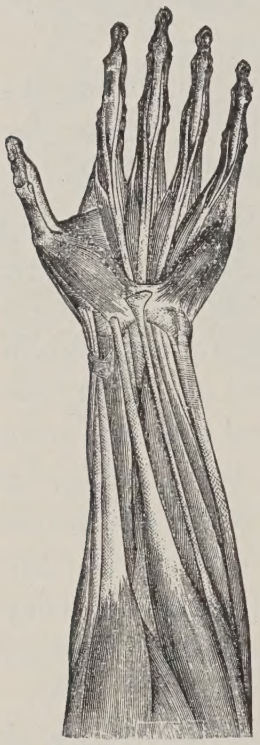


FIG. 292.—Muscles and tendons of the forearm. (*Holmes.*)

As we learn more about the structure of these parts of the skeleton and see how few improvements could possibly be suggested, we appreciate what a wonderful mechanism it is.

586. The Muscular System.—Our muscular system, which is rather elaborate, is a very important part of the body. The function of muscles is to produce motion. Muscles are of two general kinds—voluntary and involuntary. Voluntary muscles are those controlled by the will, such as the ones employed in picking up an object. Involuntary muscles are the muscles which operate without the control of the will, such as those that produce the heart-beat.

587. A muscle may be defined as **a bundle of muscle fibers, each capable of contraction.** The unusual thing about a muscle is that while it can contract or make itself shorter, it cannot lengthen itself. For instance, when we bend our arm by contracting the biceps muscle (the large mass of flesh at the front side of the upper arm), it has to be eventually straightened by being pulled back into place by a contraction of the triceps (the opposite muscle on the other side of the arm). Thus we say that such muscles act in opposition to each other.

Muscles which move any part of the skeleton are called **skeletal** muscles. These are, for the most part, voluntary. A muscle, such as the biceps, which bends or flexes any joint is called a **flexor** muscle, while one which, like the triceps, straightens out or extends any bent joint is called an **extensor** muscle.

588. We sometimes think of muscle as lean meat. When we buy meat at the market, we are buying muscle which came from some animal. Fat meat, or "adipose tissue," as the doctor calls it, is not muscle. If we examine a muscle under the compound microscope it looks very different from what we have previously supposed it to be—merely a piece of meat, like a piece of wood—about the same texture all the way through. Instead, it reminds one of the brown colored "tarred rope" that is used in tying up bags of grain. It is composed of hundreds of very tiny, hair-like threads or fibers. All these muscle fibers taken together make up the muscle. At your first opportunity examine any small piece of lean meat under a microscope and you can verify this fact yourself. You will then understand the real structure of muscle because by going about it scientifically—seeking to learn the truth by direct observation—you have learned what it really is.

589. How We Can Move.—The ability to move is of the greatest importance to each one of us. Nearly every motion depends upon the contraction of muscles. They must act in unison when we do even such a simple thing as to walk across the floor, and they must respond instantly to our will, or we could not even stand up, to say nothing of going ahead. How, then, are we able to cause our muscles to contract?

590. The Nature of Contraction.—Muscles may be made to contract or shorten by any one of four different means. The first of these is electricity. A man who touches a spark plug while his auto is running jumps, because the muscles of his arm and hand contract even before he knows it. Heat is the second kind of stimulus; we move suddenly whenever we touch any hot object. Certain of the chemicals will also produce contraction, as is shown when we unintentionally come in contact with strong acid.

The fourth cause and the one which is the most interesting, is a nervous impulse. These impulses are like messages passing along our nerves to the muscles; we shall learn about them later in our study of the nervous system, but it is enough now for us to know that we can send impulses into any of our voluntary muscles whenever we wish to do so, and that those muscles obey our will.

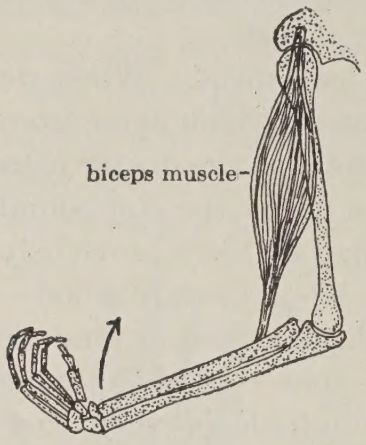


FIG. 293.—Skeletal muscles move the bones. When this biceps muscle contracts it moves the forearm in the direction shown by the arrow. (*Holmes.*)

591. Three Main Kinds of Muscle.—The three main kinds of muscle, according to structure, are the **striated** or banded muscles, which are voluntary; the plain or **smooth** muscles, such as those that produce our breathing movements or the movement of our food through the intestines; and **cardiac** muscle, which is found in the heart. Both smooth and cardiac muscles are involuntary.

592. Where the Muscle Gets Its Strength.—All the physical work we do is accomplished by the contraction of various combinations of different groups of our 500 muscles. Where then, does the muscle get its strength to do this work? The answer is simple—from the food that we eat. This food, after being digested, is carried by the blood stream and lymph and distributed to the fibers of every muscle, to be oxidized and used as a source of energy. The energy or strength of our bodies comes from the burning of this fuel-food. As we use up the food supply in our muscles by continued vigorous exercise, we become tired. This condition, known as muscular fatigue, is only temporary, for as soon as we begin to rest, more food is brought to the muscles from the blood stream, while the carbon dioxide gas, lactic acid, urea, and other waste products of oxidation are taken away by the blood stream, leaving the muscles ready for more work.

593. You have perhaps heard of what is called "the runner's second wind"; that is, when the athlete becomes very tired but

keeps on, new strength soon comes to him. This is partly due to a readjustment of the breathing movements, and partly to an overflow of animal sugar or **glycogen** (*gli'ko jen*) given out by the liver where it has been stored as an emergency fuel for use in just such cases. Being nearly pure carbon, it is oxidized almost immediately; hence the new supply of strength which the athlete feels. Obviously this supply is not inexhaustible and should not be drawn upon except as nature intended it—as an emergency fuel.

594. Keeping Our Muscles Fit.—Not only do we wish to feel well and strong at all times, but we also wish to build up strong bodies with good healthy muscles. We often admire the muscles of some pugilist or other strong man and wish that we had strength like his. Instead of wishing for it, we might well ask how he gained it. Proper diet, exercise, sufficient sleep, and regular habits of living are all necessary in the building of strong bodies.

First, you should eat three good meals every day. Do not eat between meals unless you are very hungry, and then eat only fresh fruit. You will find that certain kinds of food may not agree with you, even though these same foods may agree with the other members of your family. Find out what these foods are, if there are any, and strike them off your list.

Second, you should exercise. The blacksmith's arm, the oarsman's back, and the runner's leg muscles are firm and strong because of regular and continued exercise, light at first and increasing only very gradually. For light exercise nothing is better than walking. Keep your chest out, your chin back, your body free and easy, your eyes and ears open; and while doing these things, enjoy yourself. If you are not in the habit of a daily walk, do not attempt a long hike at first; work up to it gradually.

Third, you should have sufficient sleep. Why? Because it is while we sleep that the greatest amount of rest comes to our muscles, as it does to all the other parts of our body. At this time there is very little output of energy. The blood stream is bringing a slow but constant supply of digested food and oxygen

to the muscles and all other tissues that need it. It is also taking away from the cells the fatigue toxins and other waste products that accumulate while we are awake and active. Is it any wonder, then, that we normally wake up from a sound sleep refreshed and rested? Eight hours of sleep is a fair average, many persons requiring more. You will have to find out for yourself how much sleep you need. When you wake up rested, refreshed, and eager to get out and be doing things, you have had sleep enough. Until that time, you have not.

Fourth, you should form regular habits of living. Have regular hours for study, regular hours for eating, regular hours for work around home every day, and regular hours for retiring and rising. Even though some friend of yours can eat one or two pieces of pie at midnight and sleep well the rest of the night, his digestion may be none the better because of it. Try to use judgment in these important matters, for good health is of primary importance if you wish to succeed in life.

Interesting Projects

1. Grasp your left shoulder firmly with your right hand; then while still holding the shoulder, raise the left arm above the head. What does the hardening of the shoulder (deltoid) muscle show as to how the arm is raised?
2. While taking a deep breath hold your sides firmly with both hands. Repeat this several times. What advantage can you see in having the ribs attached in such a way as to allow them to be slightly movable?
3. If your school possesses a mounted human skeleton, examine it to learn why ball and socket joints at the shoulders and at the hips serve better than would hinge joints at these places.
4. Find out the thickness of the skull by inserting a pencil through the opening at the base. Why is this thickness necessary? Why would a thicker skull be a disadvantage?

Review

1. What work do the muscles perform for the body?
2. What advantage is gained by having the arm and leg bones attached to the pectoral and pelvic girdles?
3. Name four kinds of stimuli which cause muscles to contract.

4. How does a muscle obtain the supply of energy which enables it to contract?
5. Give four directions for keeping our muscles firm and flexible.

Define

adipose tissue
appendicular skeleton
auditory canal
axial skeleton
clavicle
cartilage
eye socket
extensor
fatigue
flexor
fontanelle
innominate bone
joint
muscle
neural canal
nervous impulse
pectoral girdle
pelvic girdle
sacrum
skull
scapula
thoracic cavity
toxins
vertebrae

CHAPTER XLII

MOST FOODS CANNOT BE USED BY THE BODY UNTIL THEY ARE DIGESTED

595. Without a doubt more of our physical discomforts and illnesses are caused by defective digestion than by any other single factor. Since this is true, it is very desirable that we understand the digestive process, and the way the various organs function, so that we may know how to avoid indigestion.

596. Digestion Defined.—Digestion is the process of changing colloids into crystalloids; or, more simply, it is the changing of insoluble food into a soluble form **which can pass through a semi-permeable membrane.**

597. Why the Need of Digestion?—All our lives we are using our strength to move about and to do our work. The energy thus expended comes from the food that we eat, when it is burned in the cells of the body. This burning or **oxidation,** as it is called, is the uniting of oxygen and food in every cell of our body. But in order to be carried around the body to supply every cell, the food must first get into the blood stream either through the walls of the capillaries directly, or by way of the lacteals. (See page 417.) This process of absorption takes place both by osmosis and by diffusion.

598. Now there are many liquids which will not osmose nor diffuse readily, and as part of our liquid food is no exception, the digestive fluids must act on it and bring about certain chemical changes which will enable it to do so. Otherwise, as one teacher expresses it, "we should starve while our alimentary canal was full of food." The chemical agents which change over our food into usable form are the digestive enzymes contained in the digestive juices.

599. The Parts of the System.—Let us first think of the digestive system as being made up of but two parts: the alimentary canal (whose walls contain certain digestive glands); and the accessory digestive glands (whose secretions flow into the canal

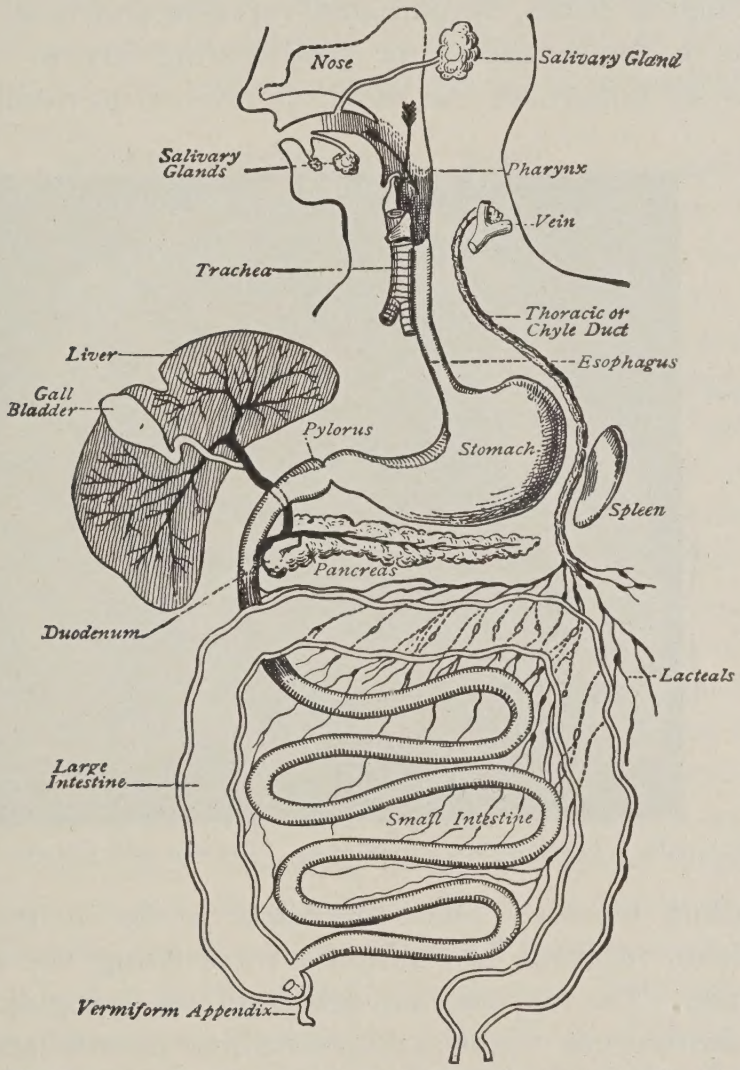


FIG. 294.—The human digestive tract with the principal glands opening into it. (*Landois.*)

through small tubes, known as ducts). The alimentary canal is divided into six parts: the mouth, the oro-pharynx, (throat), the oesophagus (*e-sof'-ag-us*), the stomach, the small intestine, and the large intestine. These are given in the order in which the food passes through them. You will find it helpful to learn

them in this order. The largest accessory glands are the liver and the pancreas.

600. Mouth Digestion.—The mouth of the human is an important organ of digestion, while in many of the animals that we have studied, such as fishes, amphibians, reptiles, and birds, it serves merely as a food-grasping or food-tearing organ. The first structures we notice are the teeth, thirty-two in number in the

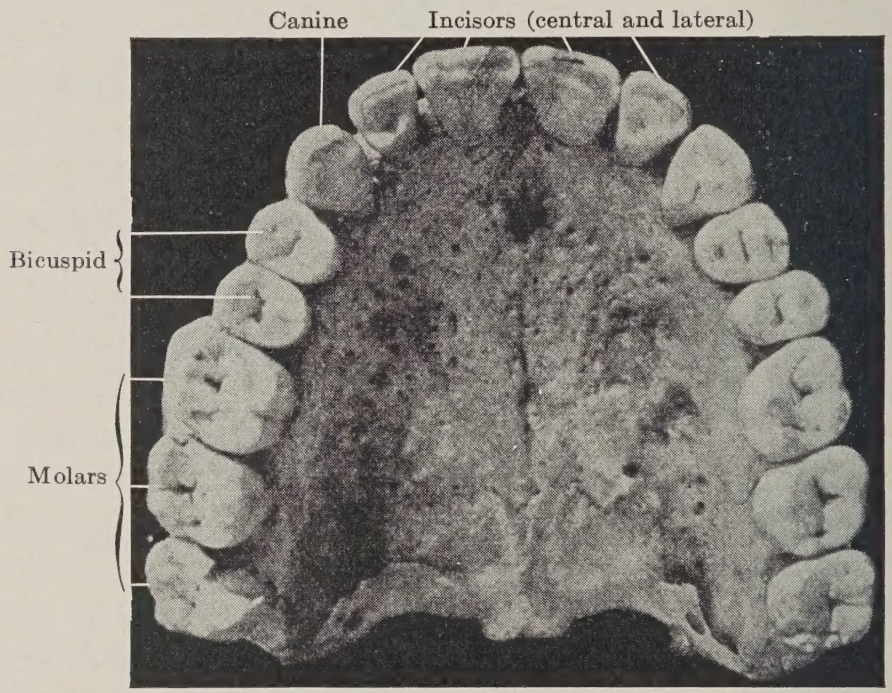


FIG. 295.—Teeth of the upper jaw. (*Corwin and Corwin.*)

normal adult mouth. There are four kinds of teeth. The eight incisors in front are adapted for cutting the food into suitable size. The four canines, although not so highly modified as in the carnivorous animals, do retain their pointed appearance. The eight bicuspids have flattened surfaces for grinding, but are smaller than the twelve molars which are the farthest back.

601. The great majority of us must be content with two sets of teeth, although rarely there is an individual who has three sets. The first, a temporary or milk set, is made up of smaller, somewhat softer teeth, twenty in number. The frequent harmful effect on the second set, of decayed cavities and abscesses in the

first set, has led many dentists to urge that we prevent these defects, as far as possible, in children's teeth. Because the second teeth follow the first very closely and because the root-canal structures of the first set are absorbed and used in developing the second set, the logic of their attitude becomes evident. So many serious organic diseases have been traced to defective, abscessed teeth that one should keep them in as healthy a condition as possible.

602. We often think of the tongue as an organ of speech, but it has a part to play in digestion, too. Assisted by the cheek muscles, it moves the food between the molars for grinding. At various points on the surface of the tongue may be seen tiny mounds of flesh, or **papillae** (*pap-il'-e*), in which are nerve endings modified to pick up the sensations caused by different chemical reactions. These are interpreted in the brain as sweet, sour, bitter, or salt. Each nerve ending can pick up only one kind of stimulus. That is, the nerve ending which is sensitive to bitter taste would not be affected by sweet, sour, or salty fluids. Only substances in solution affect these nerve endings.

603. The digestive juice, saliva, enters the mouth through tiny tubes or ducts from the salivary glands, located just below and in front of the ears, under the tongue and near the lower jaw. The saliva moistens the food, thus changing its physical nature, while its contained enzyme, ptyalin (*ti'-al-in*), acts on the starches, chemically changing them into grape sugar. Saliva is alkaline in its chemical action; that is, it tends to neutralize acids. Ptyalin has the same effect on the starches in animals that diastase has on the starches in plants. You can easily test the above-mentioned change for yourself by chewing a cracker and keeping it in the mouth for several minutes. After a time it begins to taste sweet. We are thus reminded that we need not depend entirely upon candy or sugar for our sweets.

The softened food mass is pushed back by the tongue into the throat, or pharynx, in which the chemical action of the ptyalin on starches continues. The opening into the oesophagus now receives the food mass.

604. The Oesophagus.—The digestion of starch continues during the passage of food through the oesophagus until it reaches the stomach where, in an acid medium, starch can no longer be digested. This passageway between the mouth and stomach is supplied with mucous glands which serve to lubricate the food. The oesophagus is also provided with muscles which run both lengthwise and transversely, the latter forming rings around it. These muscular rings start contracting at the upper end, automatically, as soon as the pharynx pushes the food into the oesophagus. The first ring contracts, then the next one, and so on in a rhythmic wave which pushes the food along ahead of it, much as one would force a marble along through a rubber tube by successively pinching the tube behind the marble. Perhaps you have seen a horse drink from a brook and have watched these circular muscles form consecutive constrictions for pushing the water up to the stomach.

605. Stomach Digestion.—Many persons seem to think that the stomach is the most important part of the alimentary canal. This is not correct, the most important part being the small intestine. But let us first learn something about the stomach. It is usually described as a pear-shaped muscular bag, but, as a matter of fact, it often assumes various other shapes according to the location and character of the contents. The opening from the oesophagus is guarded by a circular muscle, the cardiac valve, which, by constricting, holds the food in the stomach. The many tiny openings of the gastric glands which line the interior of the stomach, secrete gastric juice containing much water besides a relatively small amount of hydrochloric acid. Gastric juice also contains two enzymes, **pepsin** and **rennin.** Pepsin digests the proteins such as those in lean meat, nuts, fish, or the white of eggs, by changing them into proteoses and peptones, later to be broken up into amino acids in the small intestine. Rennin, the other enzyme, partly changes into curd the protein present in milk, the digestion being continued by the pepsin. There is also a physical digestion in the stomach, the heat of the body melting the fats from small pieces into tiny globules.

606. The food remains in the stomach from two to five hours according to the nature of the food eaten. During this time the lower or pyloric valve remains closed, keeping the food in the stomach until the gastric enzymes together with the muscular action of the stomach walls reduce it to the consistency of thick soup. The pyloric valve then opens automatically and the semi-liquid mass is squirted into the intestine. In cases where indigestible solids are eaten, the pyloric valve finally allows them to pass on. These two valves are sphincter (*sfink'-ter*) muscles, which operate much like the opening of a string purse or a tobacco pouch.

607. The Intestines.—The first part of the intestine consists of a long section, the **small intestine.** This is between twenty and twenty five feet in length in the average adult, and about an inch in diameter. The next section, the **large intestine,** is twice as large, being approximately two inches in diameter, although only four to five feet in length. The work done by the two intestines is so very different that we shall consider them separately.

608. The Small Intestine.—The small intestine consists of a much-coiled tube which fills the greater part of the abdominal cavity. It is made up of several thin layers of tissue. Two kinds of muscles are present in its walls, the circular and the longitudinal. As in the oesophagus, they make possible a series of contractions which force the food along through the intestine. This action is called **peristalsis** (*per-is-stal'-sis*). The intestine is supported and held in place by the mesenteries, thin bands of whitish tissue attached dorsally, much as you may have observed them in the dissection of a frog.

Why do we, like all the higher animals, need such a long intestine? Evidently it has so much more work to do in digesting and absorbing the nutrients that additional time and surface are required for doing this work. (Most foods require about twenty-four hours to pass the entire length of our alimentary canal).

609. Intestinal Digestion.—The food has gone but a short distance through the small intestine when it comes to the openings

of the bile duct and the pancreatic duct. Through these two tubes the bile (from the liver) and the pancreatic juice (from the pancreas) flow down and mix with the food mass.

Let us see, now, why they are needed at just this point. And to do so we might well see what has been accomplished thus far. Starch has been partly digested in the mouth; the proteins have been partly digested in the stomach; and the heat of the stomach has melted some of the fats into oils. But we must remember that none of the nutrients has been entirely digested, normally, when the chyme (partly digested food) enters the small intestine. Therefore the work of completing the digestive process has to take place in the small intestine.

610. The **bile,** which has a greenish-yellow color, is alkaline, and very bitter in taste. It performs four different tasks. It excretes from the liver certain wastes, such as broken-down red corpuscles. It neutralizes the acid condition of the food as it comes from the stomach. It aids greatly in the digestion of fats by one of the pancreatic enzymes, and it stimulates peristalsis.

The pancreatic juice is the most important digestive juice since its enzymes can digest a whole meal. This is made possible only by the fact that it has three enzymes—one for each class of nutrients.[1]

611. Absorption.—As we have already learned, the food which we eat has to pass into the blood stream before it can circulate around the body to be used by the various tissues and cells. This process of getting digested food from the small intestine into the blood stream is known as **absorption.** It is tremendously important and depends to a very great degree upon the processes of osmosis and diffusion. You have learned that two conditions are necessary in order for osmosis to take place: **a semi-permeable membrane** and a **difference in the densities** of the fluids on each side of the membrane.

[1] The three pancreatic enzymes are amylopsin (*am-il-op'-sin*), which acts on the undigested starches; trypsin which digests the remaining proteins; and steapsin or lipase which digests the fats by changing them into fatty acids and glycerine.

612. The Villi.—Since the walls of the intestines are muscular and not thin, special structures are needed to make absorption possible. Have you ever examined a piece of tripe (the lining of a cow's stomach) in the meat market? If so, you have noticed the numerous ridges and tiny projections rising up from it. The lining of the small intestine is somewhat the same, except that the tiny projections, **villi** (*vil'-ī*) as they are called, are like microscopic fingers growing out from the inner wall of the intestine and reaching out like tiny fingers into the liquid food mass. They have been described as appearing under the microscope like a field of grain swaying in the breeze. This appearance is due to the swaying motion of the villi, which no doubt aids in absorbing the liquid food, as does also the expanding and contracting of each villus.

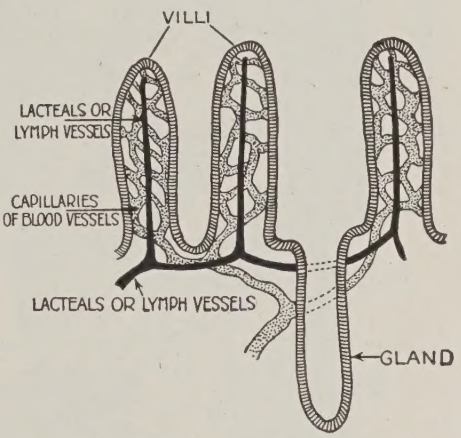


FIG. 296.—The structure of a villus. (*Corwin and Corwin.*)

A glance at the accompanying figure of a villus shows that each one of them has very thin walls and is supplied with the capillary of an artery and of a vein. Extending up into the middle of each villus there is also a lacteal (*lak'-te-al*), or special lymph duct which absorbs digested fats. Since the function of the villus is absorption, we see how admirably it is fitted structurally to do this work. The wall is so thin that the blood and the food mass come into very close contact and absorption takes place very easily. The walls of the capillaries and lacteals are likewise only one cell thick.

613. A single villus, then, contains both blood vessels and lacteals. The former absorb digested carbohydrates and proteins; the latter, digested fats. The carbohydrates are carried by the portal vein to the liver, where the excess is stored as glycogen, the rest being carried by the blood stream to the cells of the body, where energy is liberated and protoplasm is produced.

The digested fats pass on through a large lymph duct, known as the thoracic duct, to the large vein, the vena cava, which empties directly into the heart. So the fats, too, finally reach the cells of the body by means of the blood stream and supply energy, particularly heat, unless they are stored as fatty tissue.

614. The Digestive Glands.—We have referred several times to various digestive glands. Right here we might well ask of ourselves: What is a gland? What work does it do? Where are the several kinds of digestive glands?

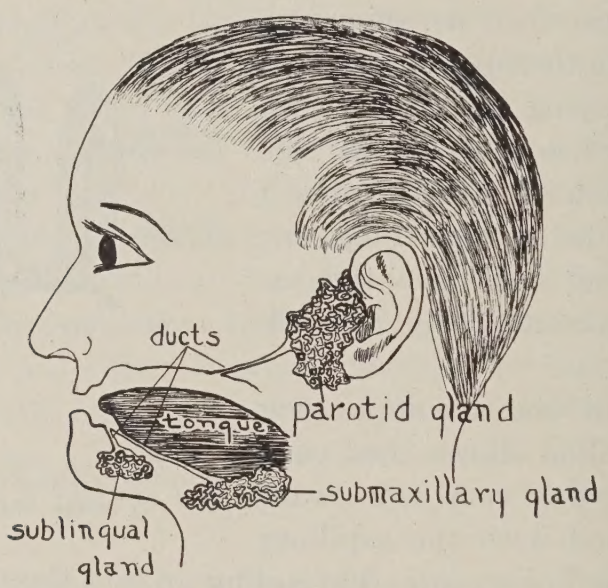


FIG. 297.—The salivary glands.

A gland is any organ which secretes or builds up any compound, taking its raw materials from the blood stream. The principal digestive glands are the salivary glands, the gastric glands, the liver, the pancreas, and the intestinal glands. The salivary glands are made up of three masses of tiny coiled tubes: the parotid glands, in front of and below the ear; the submaxillary glands, located under the jaw; and the sublingual glands, under the tongue. These all secrete the fluid **saliva** which contains the enzyme **ptyalin,** and give it off into the mouth, principally while we are eating.

Hundreds of tiny gastric glands, located in the walls of the stomach pour into the stomach their secretion known as gastric juice.

615. The **liver** is the largest gland in the body. It is of a dark, reddish-brown color, and lies below the diaphragm and above the stomach, partly covering it. Besides being a storage place for glycogen, it secretes during each twenty-four hours slightly more than a quart of bile. This bile flows down the bile duct into the intestine, where it mixes with the food mass. The presence of food seems to stimulate its secretion. When not needed in digestion the bile is held in a reservoir about as large as a pear, known as the **gall bladder.**

The **pancreas** is a thin gland, more than four inches long, lying between the stomach and the first section of the intestine. Its secretion is **pancreatic juice.** The pancreas of cattle is sold in the meat markets under the trade name of "sweet bread."

The **intestinal glands,** located in the walls of the small intestine, secrete a fluid containing the hormone **secretin** (which stimulates the flow of pancreatic juice) and several enzymes which aid in completing the digestion of protein and in changing various sugars, including cane sugar, into grape sugar which is readily absorbed.

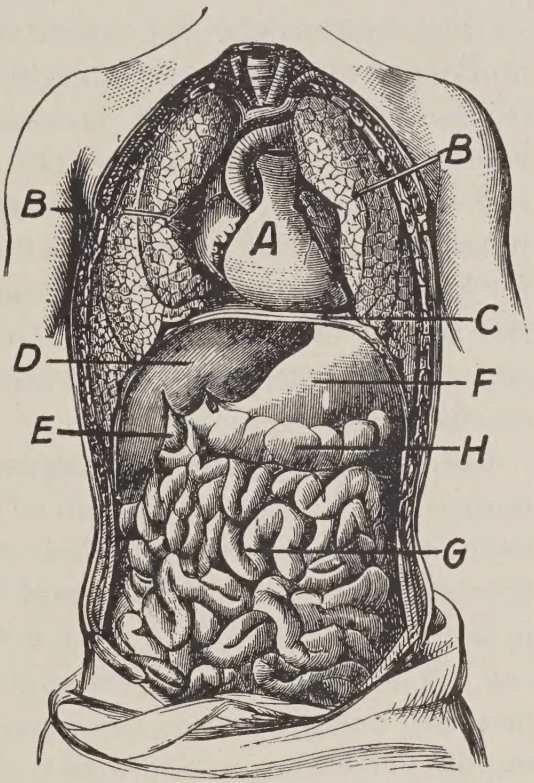


FIG. 298.—*A*, the heart; *B*, the lungs drawn aside to show the internal organs; *C*, diaphragm; *D*, liver; *E*, stomach; *G*, small intestine; *H*, large intestine. (*Holmes.*)

616. The Large Intestine.—The large intestine begins in the lower right side of the abdominal cavity, extends upward nearly to the diaphragm, then crosses to the left side and downward to the rectum. The work of the large intestine is fairly simple. Having neither digestive glands nor villi, it performs no digestion nor the absorption of digested nutritients. The glands in its

walls secrete **mucin** which lubricates the waste mass. Its principal function, however, is to absorb water from the solid wastes and to eliminate these wastes from the body.

617. *The Appendix.*—At the point where the small intestine joins the large, is found a small tube about the size of an ordinary lead pencil and from two to three inches long. This tube, known as the vermiform (worm-shaped) appendix, is closed at its free end and opens into the large intestine at its attached end. Formerly it was believed that fruit seeds and other indigestible bits of food would cause appendicitis if they became lodged here. It is now believed that appendicitis is usually an infection developed from putrified material in the large intestine. This is another reason for keeping the food mass moving along regularly, so that excessive putrefaction may not take place. Before operations became general, the disease known as inflammation of the bowels (appendicitis) was frequently fatal.

618. The Hygiene of Digestion.—There is probably less danger of wide-spread famine in the world today, than there has been at any previous period of its history. Because of the greater abundance of food and the comparatively greater ease in securing it, there is a tendency among many persons to overeat. The continuous overloading of any portion of the alimentary canal, such as the stomach, leads sooner or later to an inability on the part of that organ to do its work properly. Various spices such as ginger, pepper, cinnamon, and so on, only aggravate the difficulty. Between-meal lunches, midnight "spreads," and too much food that is hard to digest (pickles, for example), are often the cause of indigestion. The stomach, like any muscle, needs rest after a period of work.

619. Sometimes a kind of food may agree perfectly with one person and violently disagree with another. We need to experiment to some extent to find out what foods disagree with us and learn to refrain from eating them. We also need to keep in mind that the greater part of the walls of the alimentary canal is muscle tissue, which, like any muscle, needs occasional exercise to keep it in the best condition. Many foods such as the sugars,

white bread, cereals, and custards, are absorbed quickly with very little residue. When the diet is composed largely of such foods, the large intestine gets very little exercise. Its muscles become sluggish; the wastes are allowed to remain until large amounts of toxins accumulate as the result of excessive putrefaction. These toxins are absorbed along with the water into the blood stream, causing much discomfort and weakening the body generally. Cathartics only aggravate the condition. "Every action has an equal reaction." That is, after the effects of the cathartic have worn off, the intestinal muscles are more sluggish than ever. For these reasons dieticians and physicians urge that we eat some raw fruit and vegetables every day, in order to provide this section of the alimentary canal with a quantity of indigestible residue or "roughage." Thus with the large intestine distended and active, the wastes are removed, and constipation is prevented.

Interesting Projects

1. Place small pieces of cracker, softened by water, in a test tube. Test with iodine for starch, and with Fehling's solution for sugar. Then add diastase solution, warm slightly, and allow to stand for a few minutes. Test for starch and for sugar as before. How do the last results differ from those first obtained?
2. Prepare artificial gastric juice in the following manner: Add 7 to 8 cc. of concentrated hydrochloric acid and a little active pepsin to one quart of warm water. After being thoroughly shaken divide the mixture into several portions and place in bottles. Into one of these place a piece of lean, rare meat cut into small pieces. Into another place a spoonful of hamburg steak. Into a third place the white of a soft-boiled egg. Into a fourth place a piece of cheese and in a fifth some fried egg or fried meat. Keep the bottles stoppered and in a warm place. Shake them frequently to bring the various nutrients in closer contact with the artificial juice. Examine the bottles at short intervals during the first hour, then as occasion permits during the following twenty-four hours, and determine the effects of cooking and the rate of digestion of these different proteins.

Review

1. What causes the food to pass along through the alimentary canal?
2. Why must the small intestine be so long?

3. What are the principal causes of indigestion?
4. What are some ways of preventing indigestion?
5. Name two functions of the small intestine. Describe one special adaptation of the intestine for performing each of these functions.
6. In tabular form give (*a*) the parts of the human alimentary canal, (*b*) the digestive glands connected with each part, (*c*) the enzymes in each digestive juice, (*d*) the nutrients acted upon by this enzyme, and (*e*) the changes produced in the nutrient by the enzyme.
7. Describe in detail the digestion which takes place in the human stomach.
8. Name and describe the special structures in the small intestine, which are adapted for the absorption of digested food.

Define

accessory gland
alimentary canal
capillary
cardiac valve
colloid
crystalloid
diffusion
enzyme
gland
lacteal
mesentery
oesophagus
pepsin
peristalsis
peptone
proteoses
ptyalin
pyloric valve
rennin
roughage
sphincter muscle
villus

CHAPTER XLIII

HEALTH IS LARGELY CONCERNED WITH THE PROPER CHOICE AND USE OF FOODS

620. We have noticed how roots of plants push out in all directions, constantly seeking the soil water and the minerals dissolved in it. We know that out over the sea the gulls soar hour after hour in a lifelong search for sustenance. Certain mammals are always competing, and sometimes ferociously attacking members of their own group to obtain some choice bit of food. And so we find this urge for maintenance of life so strong that it influences the behavior of all living things in countless ways.

We human beings, too, are far from being immune to this same urge. Armies of men still fight for wealth, as represented by fertile land and food abundance. And today agriculture, the source of our food, is the solid foundation on which our civilization rests. It is but natural that measures to aid and encourage our farmers are considered of first importance in the legislative halls of government.

621. The Changes in Kinds of Foods and Cooking Methods. The development of different varieties of foods, methods of cooking, and the discovery of new edible substances have been progressing through the centuries. There was a time, long ago, when the use of fire was unknown in the preparation of food. All kinds of foods were eaten raw, just as wild animals eat them now. Meal time was at any time when food was at hand. And often, during the colder seasons, man was reduced to a fare of dried nuts or roots, with stark famine an ever-present possibility. The practice among primitive peoples of burying their dead with implements for eating and hunting has indicated this ever-present

fear of famine as well as a regard for the care of their dead. Incidentally, burial customs have been of great assistance to us in learning about the habits of eating and other aspects of their lives.

622. It is believed that these early peoples learned of the value of cooked meat by watching wild animals devour the victims of a forest fire. There is evidence that the first method of cooking was roasting or broiling; that is, the food was placed directly on the live coals, or held in the flames. Graves which were made at later periods, have been found to contain utensils for boiling foods in water.

Still later we find some of the tribes attempting to raise certain plants for food. Other tribes domesticated such animals as cattle and sheep in order to make their food supply more certain. Such changes in methods of living prevented the tribes from roaming about as their ancestors had done, and formed the beginnings of nations.

This progressive development of foods makes it possible for us to have delicacies which were not within the command of a Roman emperor, because in his time they were not in existence. Julius Caesar, conqueror of all the known world of his time, might have envied your ability to enjoy ice cream in the heat of a midsummer day.

623. Not the least of the hardships suffered by Admiral Peary in his successful quest of the North Pole, was the difficulty in transporting and preserving sufficient food of the more perishable kinds, such as fruits and vegetables. But this was in 1909 or earlier, and when we contrast conditions during Admiral Byrd's equally successful quest of the South Pole by air, we find him and his men enjoying most of the foods available in the markets at all seasons.

624. Changes in Methods of Living.—Before the middle of the last century, the greatest problem concerning food was to find and to preserve a sufficient amount. Since then, the greatest problem has been to adapt available foods to the demands of new ways of living. Up to that time, factories and offices had not claimed the millions of workers they now employ. Farming, hunting, fishing

and the many household tasks connected with these occupations kept people busy in a kind of work that gave them an abundance of exercise. Many foods were coarser than they are today, and digestive systems were well adapted to them.

The invention of machines, such as reapers and lathes, made necessary the introduction of factories. These in turn brought

FIG. 299.—The first Thanksgiving. Early New England settlers feeding their Indian friends. (*Underwood & Underwood.*)

about a release of thousands of workers from the fields. Many of these men and women, who, under former conditions would have remained on the farms, drifted into the cities and larger towns, partly because of necessity and possibly, just as often, through choice. Bodies built for an active life outside thus became subjected to very different conditions. Now, both the home life and the business life were spent indoors. Perhaps the man spent his days in a machine shop or at a lathe in a factory, where he saw the sunshine for only a short period, exercising but a

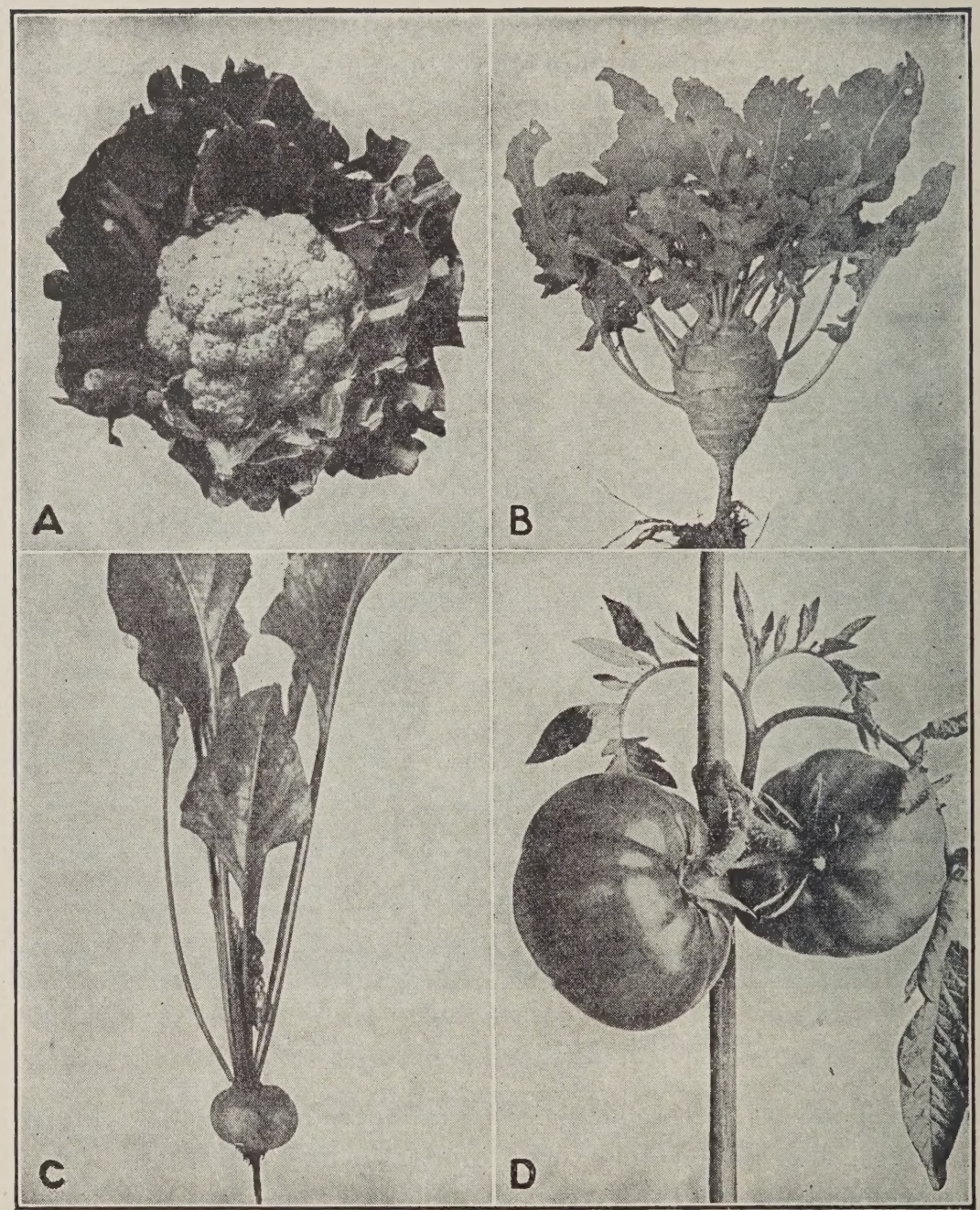


FIG. 300.—Parts of plants which are used as food. *A*, the flower of the cauliflower; *B*, the stem of kohl-rabi; *C*, the root and leaf of the beet; *D*, the fruit of the tomato. The fact is also illustrated that food may be stored in almost any part of the plant. (*Atwood and Heiss.*)

few of the many sets of muscles of his body. Possibly the woman spent hours standing behind the counter in a department store, or sitting at a typewriter in an office.

625. The Conflict between New Foods and an Old Type of Digestive Process.—Food, too, changed both in quantity and quality. Because of better methods of distribution and preservation, the danger of famine became lessened and more food became available to more people. Methods of refinement were introduced to please both the eye and the palate. Soon, foods became so much softer that it became unnecessary to chew them so much, and the muscles of the jaws did not have sufficient exercise. The muscles of the digestive tract also became sluggish for the same reason. And the greater attractiveness of the food made over-indulgence a common fault.

626. The present generation is struggling to adjust itself to these many changes. Because of the lack of reliable information on the part of the general public, all sorts of diet fads and reducing fads are in evidence, from the ridiculous claims of the manufacturers of fat-reducing soaps to the starvation diets which dangerously interfere with adequate nourishment of individual body cells. Such malnutrition shows its effects first in any weakened organ, because only through food can the body get the substances necessary for replacing those used by activity. Dentists have become concerned about diet because early decay of teeth, due to faulty mineral construction, regardless of scrupulous cleanliness, has added to the discomfort of a great many people.

627. The Measurement of Food Values.—Now let us see if we can find out a more scientific way of preventing disorders or annoyances which result from the wrong choices of food either in quality or in amount. It is known that minerals are necessary in the formation of the harder tissues, the bones and the teeth. Fruits and vegetables containing as they do, minerals and water, should, therefore, form an important part of our diet.

We have already learned about the principal groups of foods: carbohydrates which include the starches and sugars, the

proteins, and the fats. During our study of digestion we learned how each of these classes of foods is changed in the digestive tract so that it can be used in the body. We learned that protein

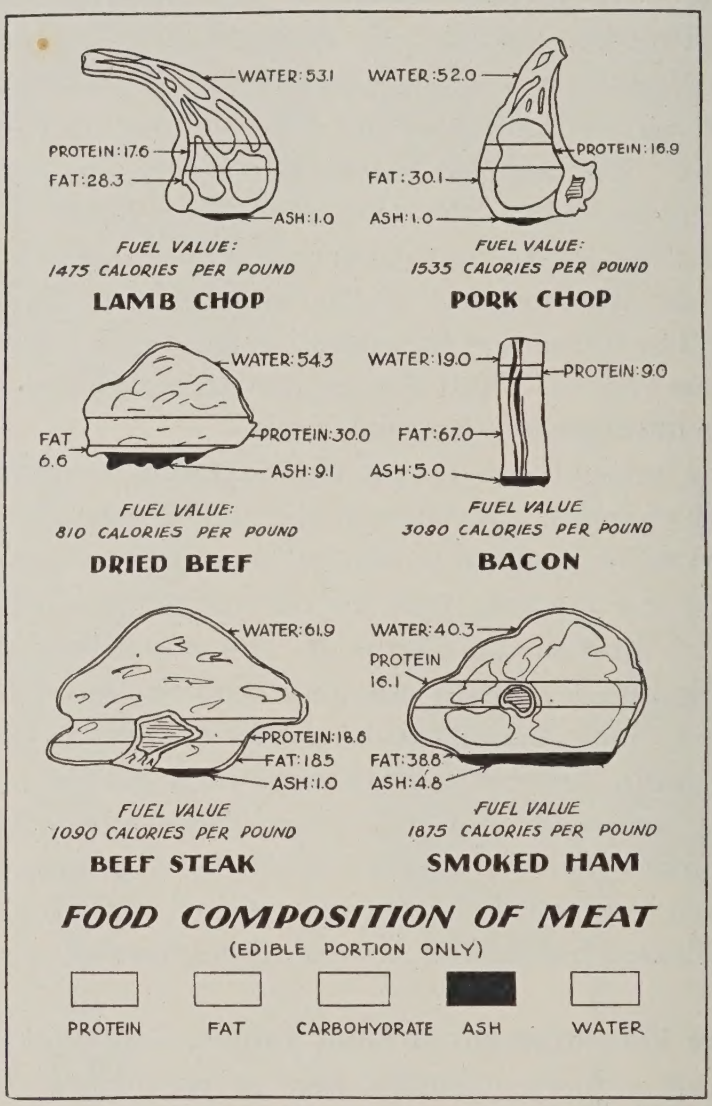


FIG. 301.—Food composition chart. (*Corwin and Corwin.*)

substances are used largely to build new cells or to replace those broken down. We discovered that carbohydrates and fats furnish energy and heat. This led us to understand that excess fats and carbohydrates are stored; and that therefore, if we wish to avoid over-weight, the simplest way, usually, is to resist the

temptation to over-eat of pastries and candy. Surplus protein is not stored, but is excreted through the kidneys. So a diet containing an excessive amount of meat or other protein may cause a strain on the kidneys, if continued over a period of time.

628. The fact that foods have a fuel or heat value has led scientists to develop a standard for measuring such food value. The unit of such measurement is the **calorie,** which is the amount of heat required to raise one gram of water one degree Centigrade.[1]

Different foods vary in the amount of heat value they contain. One tablespoonful of sugar burned in a calorimeter, or in the body, will give off 100° of heat Centigrade. In determining one's individual needs in the matter of calories, one's size and age are factors, the kind of activity in which one engages, and the length of time it is carried on. Likewise the climate and season of the year must be considered.

629. It will be interesting to make out an individual menu for a typical day, that is, a day representing the customary activities in their usual amounts. Determine how much of this typical day is to be spent in sleep (this should be at least eight hours); how much is to be spent in study when most of the muscles are inactive; and finally, how much time is to be spent in each of the different kinds of exercise—light, active, strenuous, and very strenuous.

Look at the end of this chapter for the sections giving food values. Section 644 will give you the minimum number of calories consumed each twenty-four hours for each pound of your weight. This is for the basal metabolism which must be carried on throughout life. Even when we are asleep certain of the bodily functions are being carried on and the normal temperature of 98.6° F. must be maintained. Section 645 will explain how the consumption of calories is increased during

[1] One gram of water is about one-fourth of a teaspoonful and one hundred degrees of heat by the Centigrade scale, or one hundred and eighty by the more familiar Fahrenheit scale, are required to raise one gram of water from its freezing point to its boiling point. The instrument devised to measure these units is called the calorimeter.

different kinds of activities. And now from Section 646 select foods which, when added together will give as a total, the amount you will need for **your typical day.** Be sure to include some of each of the food groups in your list.

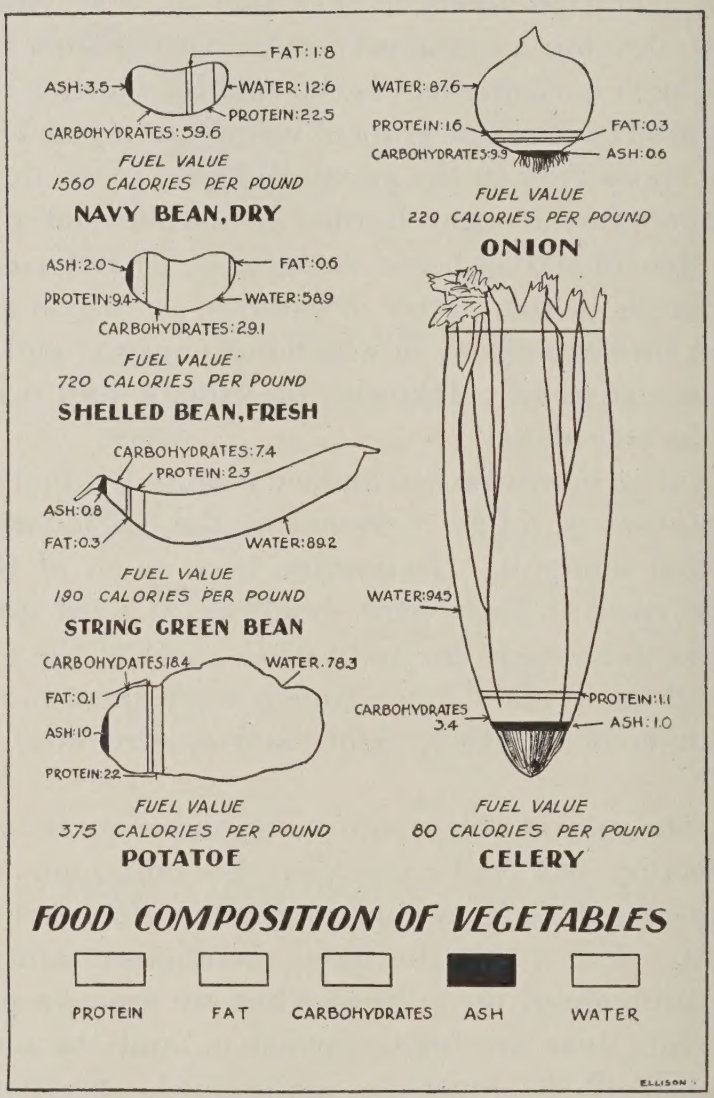


FIG. 302.—Fresh vegetables are one of our most important sources of vitamins. (*Corwin and Corwin.*)

630. The Vitamins.—Just being careful to get the proper number of calories, however, will not keep us in good health. Ages ago, the Greeks knew that oftentimes sailors with an abundance of food were subject to scurvy, a disease due, we now

know, to the lack of a substance found mostly in fresh fruits and vegetables. This substance and others in the same group are the vitamins.

The emphasis that recently has been placed on cod liver oil because it contains "sunshine vitamins" reminds us that besides making the development of all our foods possible, the sun is important as a health-giving force.

631. We have learned how all animals and certain plants are dependent on the green plants for food. We have also learned how necessary sunlight is as the source of energy in photosynthesis. Many of the fruits and green vegetables could be readily replaced by cheaper foods, if the food values other than the vitamins were considered. But the vitamins as foods regulating certain functions in the body, give fresh fruits and vegetables a place of first importance. The effect of sunlight on the skin in stimulating and making possible the development of vitamins within the body itself has added interest to many outdoor recreations.

632. It was not until 1917 that a Polish scientist discovered this important class of foods. Although the chemical composition of all vitamins is not known as yet, it has been learned that the lack of any one vitamin leads to a definite physical defect. Their discovery followed the observation that a diet which seemed to be correct in its balance of protein, fat, and carbohydrate content did not result in complete nourishment. This fact, which was noticed especially with respect to cooked foods, led to the belief that certain cooking processes reduce the amount of these substances and in some cases destroy them altogether. For example, when vegetables are boiled and the water in which they are boiled is thrown away, most of the valuable vitamins are usually lost. Now we understand why physicians and dieticians are urging us to include some fresh raw fruits and vegetables in our diet every day.[1]

633. The Need of a Mixed Diet.—We need a variety of foods in our diet, because they stimulate the appetite and because no

[1] The different vitamins and their effects are given at the end of this chapter.

one food is perfect in every way. Milk is well-balanced and is our most important single food, but it lacks two important substances, iron and vitamin C. Moreover, it is digested so

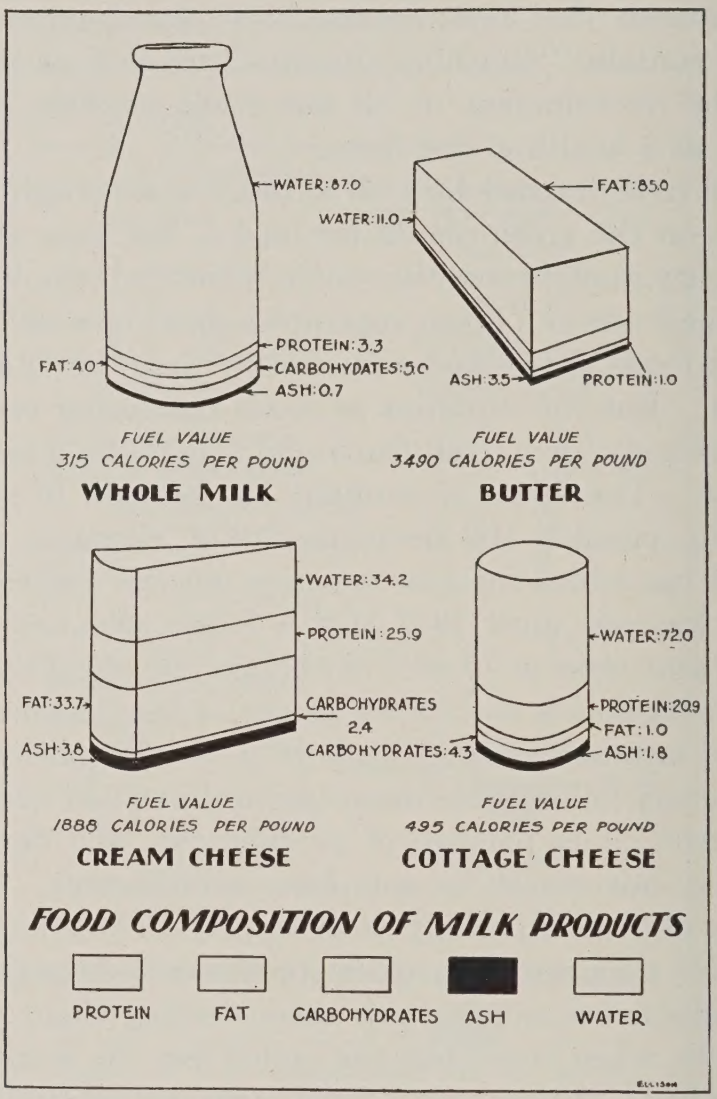


FIG. 303.—Food composition chart. (*Corwin and Corwin.*)

easily and absorbed so quickly that a diet exclusively of milk would fail to give the intestinal muscles of an adult sufficient exercise to keep them in good condition, for only through use do muscles maintain the ability to function. Different foods stimulate the senses of taste and smell, and these in turn influence the flow of digestive enzymes.

634. The Protection and Preservation of Foods.—The great variety of foods now available at all seasons of the year reminds us

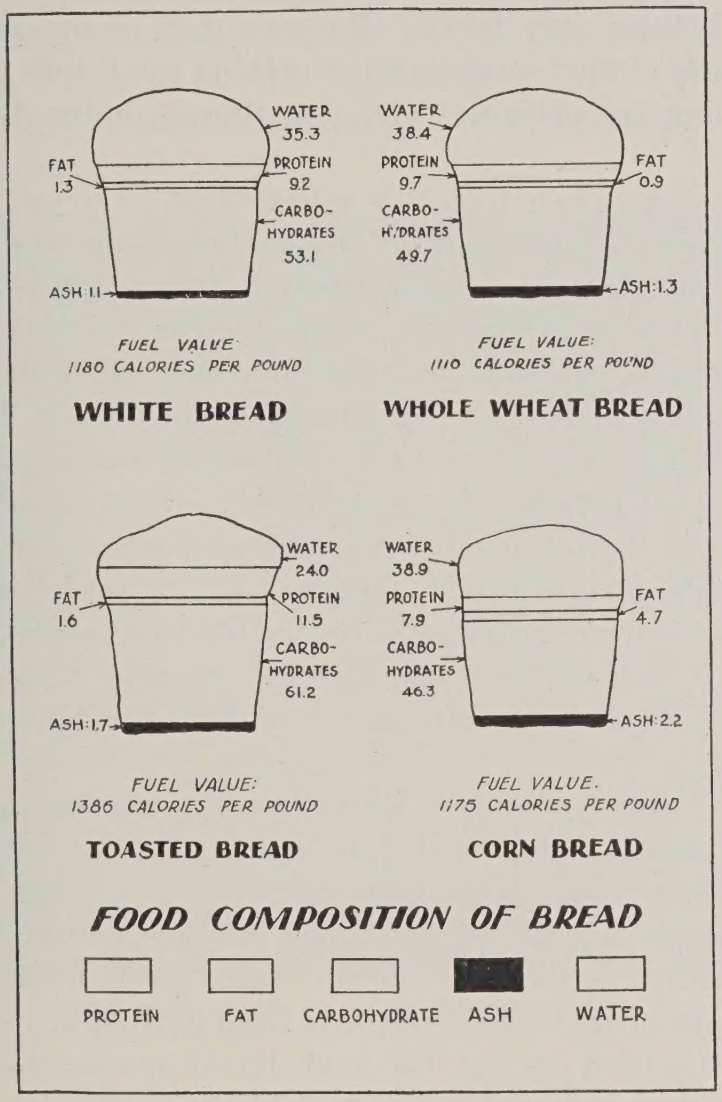


FIG. 304.—Food composition chart. (*Corwin and Corwin.*)

that methods of protection and preservation are constantly being improved. Artificially refrigerated cars and ships speed tropical fruits and vegetables to the north in such quantities that they become available to nearly everyone. The public is assured a protection from contaminated foods by laws which are enforced in all our progressive communities.

We have learned that decay is caused by certain kinds of bacteria. Therefore any device that keeps these organisms out of foods, or prevents them from carrying on their destructive processes, will prevent decay. Bacteria may be prevented from causing decay of food substances by making conditions unsuitable for sustaining the activities of living things, or by the canning process.

635. When we place food in a refrigerator, or freeze it rapidly, the environment is too cold for the bacteria to reproduce, or to carry on other life processes actively. Meats, fruits and milk are often protected in this way. Such foods as jellies and pickles are protected by the addition of some preservative, such as concentrated sugar, salt, spice, or vinegar solutions, in which it is impossible for the bacteria to live. Primitive people, such as the American Indians, usually protected meats by a process of smoking, a method in use today in the preparation of hams and other smoked meats. If all moisture is removed from a food product, life becomes impossible for bacteria. This is the reason why flour, if kept dry, may be stored for months without danger of decay. Fish and fruits, too, are sometimes dried and preserved in this way.

636. The canning process provides the basis for one of our largest industries, and foods preserved in cans and jars are familiar to everyone. This process depends for its success on two factors. First, heat is applied which kills the bacteria of decay usually present; second, the sterile can or jar is made air-tight, by sealing, to prevent other bacteria from getting in. When the can or jar has been opened, the food should be consumed as soon as fresh food of a similar nature would be, because the bacteria of decay may now attack it.

637. Pasteurization.—Nearly everyone is familiar with pasteurized milk. In most cities this method of protecting the milk supply is compulsory. The nature of milk is such that it may become readily contaminated with an abundance of bacteria. That is, it is an organic food, and it is moist. When it is first taken from the cow the temperature is suitable for rapid reproduc-

tion of any bacteria which may have come from the cow, as in bovine tuberculosis, or which may find their way into the milk from dirty containers or unsanitary workers. Serious epidemics of diphtheria, scarlet fever, septic sore throat, and typhoid fever have been traced to infected milk supplies. The older practice of distributing unpasteurized milk in open containers made such contamination easily possible.

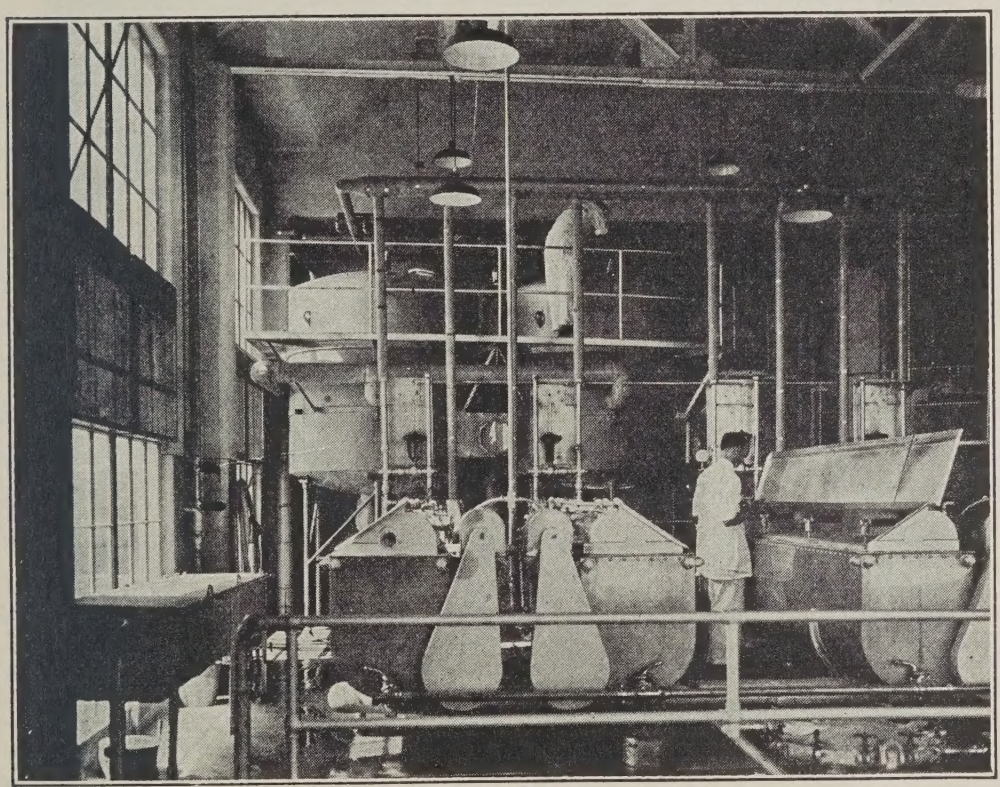


FIG. 305.—A pasteurization plant. This process adds to the cost of the milk, but it prevents the transmission of diseases commonly spread in this way. (*Corwin and Corwin.*)

638. Most modern dairies take a justifiable pride in their methods of securing cleanliness and they deserve the confidence of the public. In such dairies human hands often have no contact with the milk at all. Milking machines extract the milk; pipes conduct it to pasteurizing machines; bottles are sterilized; and, finally, bottling and capping machines pass it on to the cooling equipment where it is held until ready for delivery to the consumer.

Pasteurization gets its name from the great French scientist, Louis Pasteur, who discovered the principles on which this process is founded. He did not discover the process itself, however; it was developed later. The process involves three principal stages. First, the milk is heated to about 145° F. for at least twenty minutes. This kills most of the bacteria, especially those which

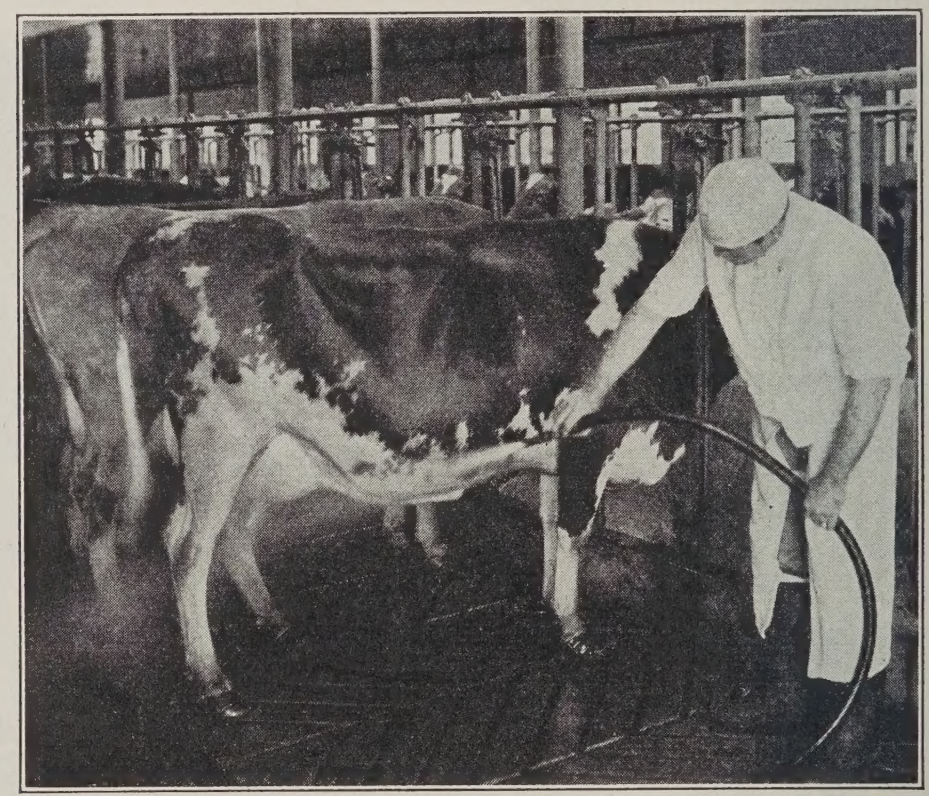


FIG. 306.—Many sanitary precautions must be taken, if the milk is to be kept from disease-producing germs. (*Photo by A. E. Cawood.*)

cause diseases. Second, it is cooled quickly. This cooling prevents any bacteria which may remain from reproducing rapidly. Third, the milk is sealed in sterile bottles and kept cool until delivered.

639. It should be remembered that pasteurization kills only those germs that were in the milk when it was pasteurized. If exposed to flies, or poured over the lip of a contaminated bottle, it, too, will become contaminated.

The infinitely small size of bacteria is indicated by the fact that a teaspoonful of milk may contain four thousand of them and yet, in most cities, be considered high-grade milk. In some localities, milk with as many as four hundred thousand bacteria in a teaspoonful may be legally sold. Even this latter number could not be detected by the unaided eye or by the taste, until decomposition had started.

640. Beverages.—Undoubtedly good water is the best beverage because it is such a necessary part of our diet, and because it contains no stimulant in the form of a drug. Coffee and tea are appetizing and their use is widespread. Each depends for its stimulating effect on the same kind of drug. Just how harmful the ordinary use of tea and coffee may be, has been the subject of much controversy. There are adults whose nervous systems are such that the mildest form of stimulant has a noticeable effect. It is generally agreed that no growing boy or girl should be permitted stimulants of any kind. Many careful tests on adults in normal health, who feel no appreciable effects from occasional indulgence, have failed to reveal resulting defects that are definitely harmful and permanent. The fact that strong, black coffee is sometimes used for its stimulating effect, and the usual necessity of refraining from the use of tea and coffee when training for athletic events indicate that their use should be limited.

641. The effect of alcoholic beverages is more pronounced. Alcohol is frequently used on tissues in the biological laboratory to harden them. When taken in a beverage, alcohol has a similar hardening effect on living tissues, which in time reduces their ability to function. It has been demonstrated that alcohol causes certain permanent changes in the fatty substance which surrounds many parts of the nervous system. It is this action which causes the intoxicating effect. Although many believe it to be due to over-stimulation, this is really a narcotic action. Control of the nervous system is lost, resulting in erratic and unreasonable decisions and conduct.

642. Tobacco.—The custom of smoking in connection with the more social side of living makes it advisable to consider its action here. The use of tobacco for chewing or as a snuff is giving way to its use for smoking. This latter use is almost universal among certain social groups. Again we are dealing with a narcotic. Just how harmful it is depends again on the individual and on the extent of its use. Upon some persons it has a definite poisoning effect, causing skin eruptions, nervousness, and digestive disturbances. Others suffer no appreciable harm from it. But there is undoubtedly some harm, especially to growing boys and girls, because the smoke hinders the action of the haemoglobin of the red corpuscles in combining with oxygen. This leads to an incomplete oxidation of food substances in the tissues, which, in turn, limits the amount of energy available for use; the result is a weakening effect. Whether the gratification of an appetite, or the satisfaction of being considered "sociable" are sufficient recompense for the harm caused by tobacco is a question which can be answered best only by the individual. It is always unwise to place a mortgage either on future endurance or on health.

643. Health Rules.—And now we come to a few conclusions which may help us to live more comfortable and healthful lives.

First, eat regularly. Food should not be taken at too frequent intervals. The organs of the alimentary canal are largely made up of muscles which need periods of rest. The sense of hunger does not necessarily indicate a physical need for food; nor does absence of hunger necessarily mean that food is not needed. One may form regular habits of eating, regardless of the presence or absence of hunger pangs.

Second, eat but little when overtired, worried, angry, or under emotional stress of any kind. The food will remain in the digestive tract without digesting, and the bacteria will act on the food, forming gases which cause distress.

Third, do not depend upon the appetite as a guide in your choice of food. Some boys and girls would attempt to live on ice cream, cake, and candy if they allowed themselves to be thus guided.

Fourth, eat fresh fruits and vegetables, both for the minerals and for the vitamins which they contain.

Fifth, avoid exercising strenuously just after meals. The blood supply should not be forced to flow more abundantly to the surface muscles when so much energy is needed for the digestion of the food.

FIG. 307.—Outdoor exercise promotes health. (*Courtesy of the Playground and Recreation Association of America.*)

Sixth, do not eat too heavily of protein foods such as meat, eggs, and cheese. Excess protein is not stored, but is thrown off as waste, mostly through the kidneys. These organs may become overworked and weakened.

Seventh, try to keep happy during your meals. Have you ever noticed how much more you can eat and how much better the food tastes when you and everyone around you are happy? Light, pleasant conversation will do you more good than a digestive pill possibly could, if you are in normal health.

644. The information necessary for making out the menu mentioned in Section 629 is given in Sections 644 to 648 inclusive, below.

A growing girl or boy requires ten calories a day for each pound of weight when asleep. That is, a boy who weighs 125 pounds requires 1250 calories each day to maintain his basal metabolism.

645. Every kind of activity, even the mildest, adds to the number of calories required, as follows:

(*a*) For the time spent when sitting quietly, add three-tenths of a calorie for each pound of weight for each hour. That is, the boy mentioned in Section 644 would add three-tenths of 125 multiplied by the number of hours spent at reading or studying.

(*b*) For light exercise add six-tenths of a calorie for each pound of weight multiplied by the number of hours spent at this kind of exercise.

(*c*) For active exercise add one and six-tenths calories for each pound of weight multiplied by the number of hours spent at this kind of exercise.

646. The list below is not entirely accurate because of the variation in the proportion of different nutrients in any one kind of food. There is also a variation in the size of the servings, but each of the following portions contains *approximately* 100 calories.

Keep in mind that the number of calories of fat should equal slightly less than one-half the number of calories of carbohydrate food for each day. The total number of calories of protein in the diet should be about one-fifth that of the total number of calories in the daily diet.

Sirloin steak	medium serving
Hamburg steak	one medium cake
Corned or roast beef	small serving
Beef loaf	medium serving
Roast veal	medium serving
Roast lamb	medium serving
Roast pork	medium serving
Roast or boiled ham	small serving
Bacon, fried	4 or 5 small slices

Frankforters	one
Roast chicken	small serving
Halibut, haddock or cod	large serving
Salmon	medium serving
Sardines	3 to 6
Oysters	12 small
Eggs, raw or cooked	1 very large
Baked beans	one-third cup
Cabbage, shredded	5 cups
Corn, canned	one-third cup
Lettuce	two large heads
Macaroni	one cup
Parsnips, creamed	small serving
Peas	three-fourths cup
Potatoes, boiled	one large
Tomatoes, canned	1¾ cups
Apple sauce	three-eighths cup
Bananas	one large
Blueberries	one cup
Orange	one very large
Peach	three
Pineapple, canned	one slice, with juice
Strawberries	one-third cup
Butter	one tablespoonful
Milk	small glass
Bread, white	thick slice, medium size
Saltines	six
Ice cream, average	2½ tablespoonfuls
Apple pie	1½″ sector (diameter 9″)
Custard pie	2″ sector (diameter 9″)
Doughnut	one-half
Sugar	two tablespoonfuls

647. The vitamins regulate many body functions. They help to promote growth and to maintain the health of the tissues. Vitamins are necessary in the diet so that the body may use the nutrients

Vitamin A promotes growth. Its absence leads to sore eyes. An important source is milk.

Vitamin B maintains the health of the tissues. Its absence leads to beri-beri. Whole wheat grains contain this vitamin.

Vitamin C also maintains the health of the tissues. Its absence leads to scurvy. Sources are lemons, oranges, tomatoes. Except in tomatoes, it is destroyed by heat and drying. This vitamin is preserved in canned tomatoes.

Vitamin D assists in maintaining vitality. Its lack leads to a disease known as rickets. Sources are sunshine, cod liver oil, yeast, and fresh green vegetables.

648. In regulating many of the body functions, minerals and water are as important as the vitamins. All the chemical changes in cells take place because of the interaction of fluids of which water is the base. Water also holds the products of digestion in solution. Water is especially abundant in the fruits and vegetables.

Minerals enable the tissues to carry on their functions. Iron enables blood to carry oxygen. Calcium and phosphorus are necessary for the development of the teeth and bones. Sodium and potassium keep the blood at a certain alkalinity. Iodine is necessary as a factor in normal growth. Minerals are found in meat, milk, vegetables, fruit, eggs, and whole cereals.

The information supplied by Sections 644, 645, 647 and 648 is taken, with modifications, from Bulletin 28—Atwater and Bryant—U. S. Dept. of Agriculture, Office of the Experiment Station.

The list given in Section 646 is condensed from a more extensive one to be found in Meredith's "The Health of Youth."

Interesting Projects

1. From a book on anthropology, learn how information about early peoples is obtained when there is no written record.
2. Write a paragraph on the relationship between the development of agriculture, and the development of stationary villages by wandering tribes.
3. Explain why it was possible for Admiral Byrd's men to have a greater variety of foods than Admiral Peary's men could have.
4. Describe the changes in table etiquette since the Middle Ages. (References from your readings in historical novels such as "Ivanhoe" may be used.)

Review

1. What is the relationship between diet and occupation?
2. Why must our diet contain both calories and vitamins?

3. Why should some of our foods be cooked? Why should some of them be eaten raw?
4. Under what conditions may dieting to reduce weight be very harmful?
5. How has the development of many machines changed the relationship between foods and the human body?
6. Define the terms *calorie* and *vitamin.*
7. Describe several different methods of preserving foods.
8. Describe the process of pasteurization.
9. What are the physiological effects of alcohol and tobacco on the nervous system?

Define

basal metabolism
calorie
calorimeter
carbohydrate
contamination
epidemic
narcotic
pasteurization
protein
vitamin

CHAPTER XLIV

THE CIRCULATION OF BLOOD MAKES THE INDIVIDUAL A COMPLETE WHOLE

649. The circulatory system is often called "the railroad of the body." The heart is the power plant; the blood vessels are the miles of railroad tracks; the liquid blood carrying its load is the train; all the cells of the body are the people to whom and from whom the freight is shipped.

It is so necessary that this great transportation system of ours supply the needs of all the cells that when any part of the body is shut off from the circulating blood stream—even for a short time—that part of the body begins to die. And yet all of the lower invertebrates, such as jellyfishes and sponges, have no circulation. They are so simple that they absorb the oxygen and food into their bodies directly from the outside, giving out their wastes in much the same way. They are too low in the scale of life to need a transportation system.

650. Parts of the System.—There are two parts to the circulatory system—the heart and the blood vessels. These blood vessels are of three kinds—arteries, capillaries, and veins. It is wise to learn them in this alphabetical order since it is the order in which the blood passes through them. These tubes vary greatly in size. Some arteries and veins are no larger than a pin; others nearly equal the size of a pencil. The capillaries are much smaller, the largest being about the size of a pin, and by far the greater number are so tiny that they can be seen only under the microscope. We shall learn presently why capillaries need to be so small.

651. An artery is any blood vessel through which blood is pumped **away from** the heart. A vein is any blood vessel through

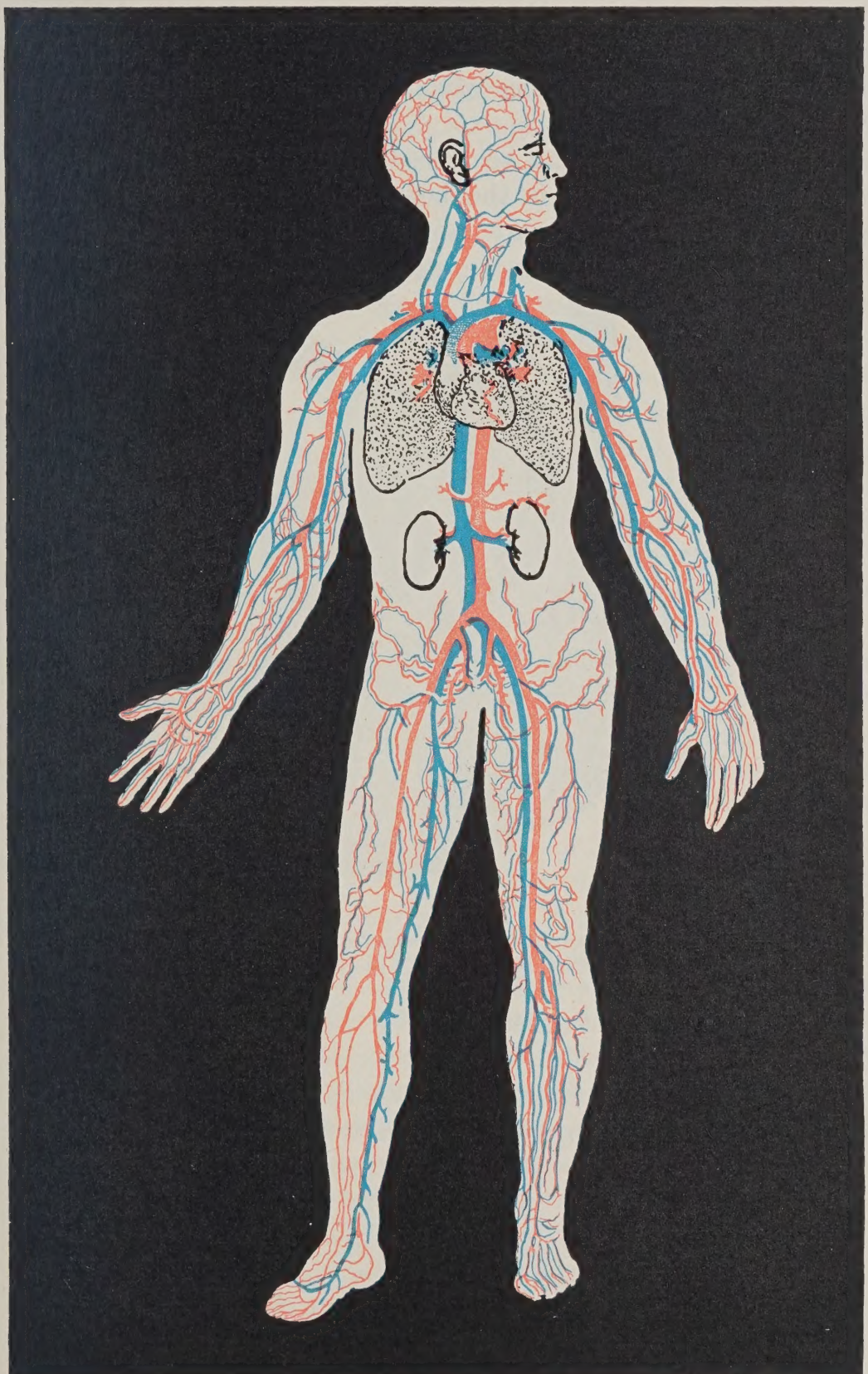


FIG. 308.—Diagram of the human circulation. Arteries are colored red; veins, blue. (*Bundy.*)

which blood returns to the heart. The capillaries make up the network of very tiny tubes which connect the arteries and the veins.

652. The Heart.—The heart is the fundamental part of the circulation, because it is the heart that pumps the blood all around the body. It is a common mistake for students to get

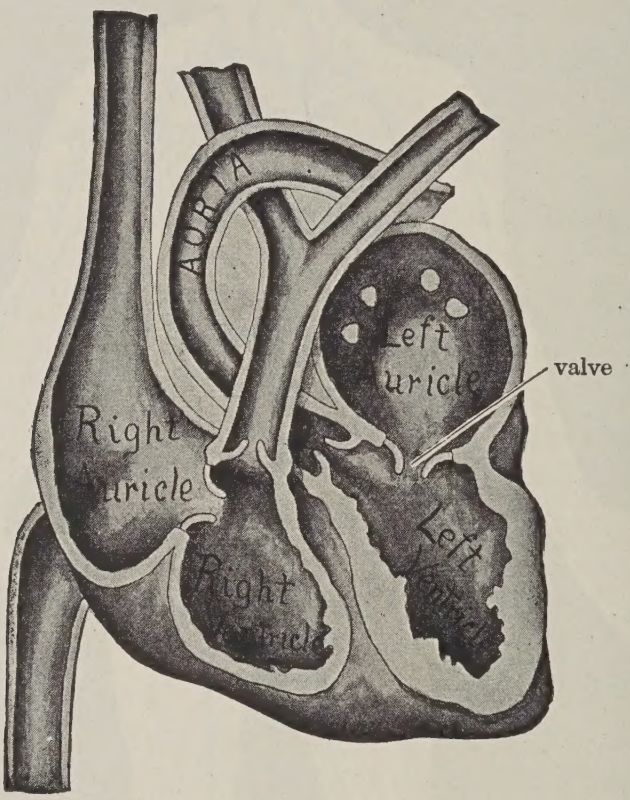


FIG. 309.—Diagram of the human heart, showing the valves. (*Farr, "Internal Medicine for Nurses" Lea & Febiger.*)

the idea that the heart purifies the blood. This is not true. **The heart is a pump** and nothing else. Although it never ceases pumping during life, the cardiac muscle of which it is made up, like any other muscle, must have periods of rest. But the rest periods are very short—only between one beat and the next one. The adult human heart normally beats seventy-two times per minute, so you see how brief the rest periods are.

The human heart, which is about the size of the fist, is divided into right and left halves. There are four chambers, two receiv-

ing chambers, or auricles, above, and two pumping chambers, or ventricles, below. On each side of the heart the auricle is separated from the ventricle by strings and flaps of muscle which serve as valves and thus prevent backflow of the blood. Each ventricle has an artery leading out of it. There are veins leading into each of the two auricles.

A study of the accompanying diagram will make this clear.

653. How the Blood Is Made to Circulate.—Each time the two ventricles contract, the blood which has come down from the auricles, is spurted out into the arteries, thus causing what we know as the pulse. Immediately following this contraction, the ventricles dilate, or enlarge, and the blood in the auricles flows down past the valves and fills the ventricles again. In less than one second of time the ventricles contract again, spurting their contents out into the arteries, and thus the arterial blood is forced along as the process is repeated over and over again.[1]

654. Arteries, Capillaries, and Veins.—As the arteries extend farther and farther away from the heart, they divide and subdivide a great many times to distribute the blood through the entire body. This many-branched system of arteries leads to the system of capillaries, although there is no distinct place where an artery becomes a capillary.

Have you ever looked at the web between the toes of a live frog under the compound microscope? If so, you have seen a demonstration that you will long remember. You saw the tiny branches of the arteries and the network of microscopic capillaries, some of them only a few thousandths of an inch in diameter, running in all directions to supply, as best they can, food and oxygen to all the tissues. Capillaries are characterized by their very great numbers, by their microscopic size, and by their walls, only one cell in thickness.

[1] The frequency of the pulse varies according to age (130 per minute at birth to 65 in old age). It also increases after eating, after muscular exercise, after nervous excitement, and even after standing for some time. A person may have a pulse rate higher or lower than 72 and still be in good health.

655. Naturally the pressure of the blood is greatly reduced as it goes through this network of capillaries, and by the time it gets into the small veins, its flow is not in spurts, as it is in the arteries, but rather, a steady flow. Test this out by trying to take your own pulse from any of the veins on the back of your hand. Then press your finger on the radial artery on the inside of your wrist where the pulse is normally taken, and you will understand the difference in flow between arterial and venous blood. Count your own pulse rate before and after a few minutes of active exercise, and note the difference in the two rates. This will show you how promptly the heart responds to the call for more energy to be delivered by the blood to the muscles.

FIG. 310.—View of internal wall of a vein. The pocket-like valves aid in preventing the return of the blood from the veins back into the arteries.

Small veins unite to form larger ones, which in turn unite to form still larger veins, until all the blood returns by the pulmonary vein and the venae cavae (veins) to the two auricles.

Arteries and veins are easily distinguished. Arteries have thick muscular walls which are elastic and act somewhat like shock absorbers to the blood as it gushes into them. Their elasticity is really necessary. On the other hand veins have thin, somewhat flabby walls; they also have valves to prevent back flow, for here there is not so much pressure to force the blood along. The extremely thin walls of the capillaries permit the easy flow of liquid food and other substances through these walls to and from the cells of the body.

656. The Double Circulation.—This name is often given to the Pulmonary and Systemic circulations when taken together.

657. The Pulmonary Circulation.—The word "pulmonary" means "pertaining to the lungs". The circulation of the blood through the pulmonary system is as follows: The de-oxygenated blood, rich in carbon dioxide, passes into the right ventricle from the right auricle. The right ventricle contracts, forcing the blood into the pulmonary artery. This artery divides into two

branches, one running to each lung. Here these branches divide and subdivide, forming the network of capillaries which ramify about and supply the internal area of the lungs. From four to five per cent of carbon dioxide is given off and the same amount of oxygen is taken in. The blood stream continues from the capillaries into small veins which form larger ones and finally form the pulmonary veins through which the oxygenated blood returns to the left auricle.

658. The Systemic Circulation.—This part of the circulation distributes the load of oxygen all through the body, at the same time collecting the carbon dioxide gas. It also does other things which we shall soon learn about. The left side of the heart contains blood which is bright red in color due to the presence of oxygen in the red cells. The left ventricle contracts, pumping the blood out into the aorta, the largest artery in the body. This aorta divides into two main branches, one supplying the head, arms and upper parts of the body, while the lower branch, likewise, divides many times, supplying the lower part of the body. The capillaries distribute oxygen and food for the cells, collect the carbon dioxide gas and other wastes,

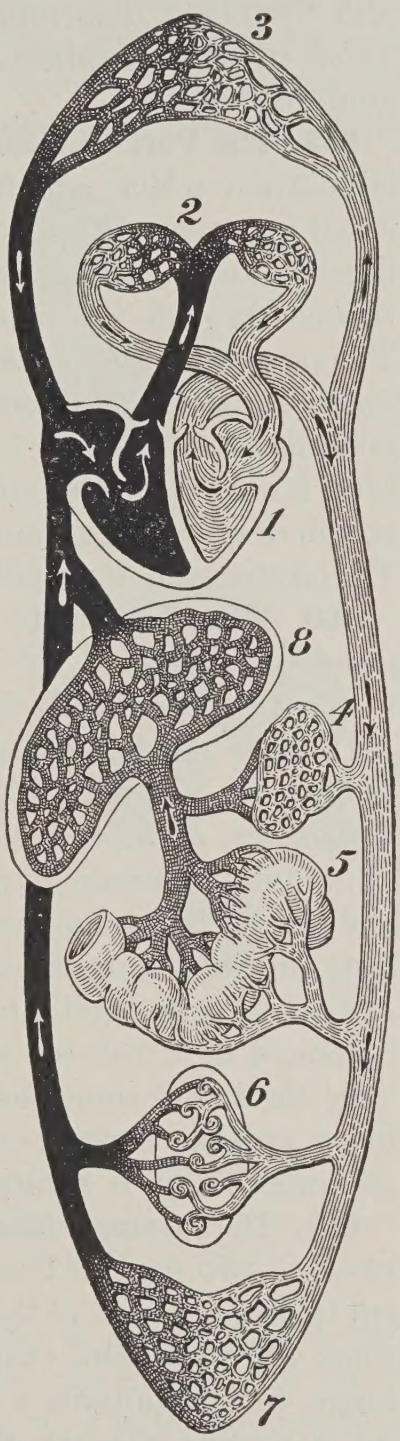


Fig. 311.—Diagram showing the blood supply of various organs. (1) Heart. (2) The lungs. (3) Head and arms. (4) Spleen. (5) Intestines. (6) Kidneys. (7) Lower limbs. (8) Liver. (*From Bowden after Dalton.*)

and the blood then returns by the numerous veins to the large venae cavae that empty into the right auricle. Thus the cycle is continued.

659. The Portal Circulation.—This is a branch of the systemic circulation which supplies the spleen, pancreas, stomach, and small intestine. From the small intestine the blood collects the digested food, carries it through the portal vein to the liver, and thence through the hepatic vein to the vena cava and heart. The purpose of the portal circulation is to regulate the amount of digested food in the blood and to keep this amount as uniform as possible at all times. If there is an excess of carbohydrates, as after a meal, the liver stores up a part of it in the form of animal starch or glycogen, retaining it until the supply becomes deficient. The glycogen is then given out again into the blood stream.

660. What Is Blood?—It is a curious fact that the blood of insects is yellowish; of clams it is blue; and of higher animals it is red. Likewise its composition varies.

Human blood is composed of three main parts: **plasma** (the liquid part which is approximately eighty per cent water), **red corpuscles,** and **colorless corpuscles.** The corpuscles are carried around in the stream of plasma, in which are dissolved many substances. The commonest of these are digested food, oxygen, salts, fibrinogen, hormones, enzymes, and various wastes such as carbon dioxide, and urea. If blood is examined after it has remained in a dish for several hours, the upper part will appear very thick and somewhat darker in color. It has clotted. The lower portion is straw-colored, very thin and translucent. This yellowish liquid is **serum.**

661. The Composition of Blood Is Ever Changing.—The blood of two persons is not exactly alike; in fact, it is very different in various parts of the body at the same time. A few illustrations will make this statement clear. Just before entering the lungs, blood contains a fairly large amount of carbon dioxide. After passing through the capillaries of the lungs it has given off from four to five per cent of this carbon dioxide and taken in the same amount of oxygen. Before exercise, the muscles

have a plentiful supply of food and oxygen. These are used up as the muscles work (contract), and the blood gets loaded up with many kinds of waste products. The blood which goes to the intestine soon after a meal, is not especially well supplied with

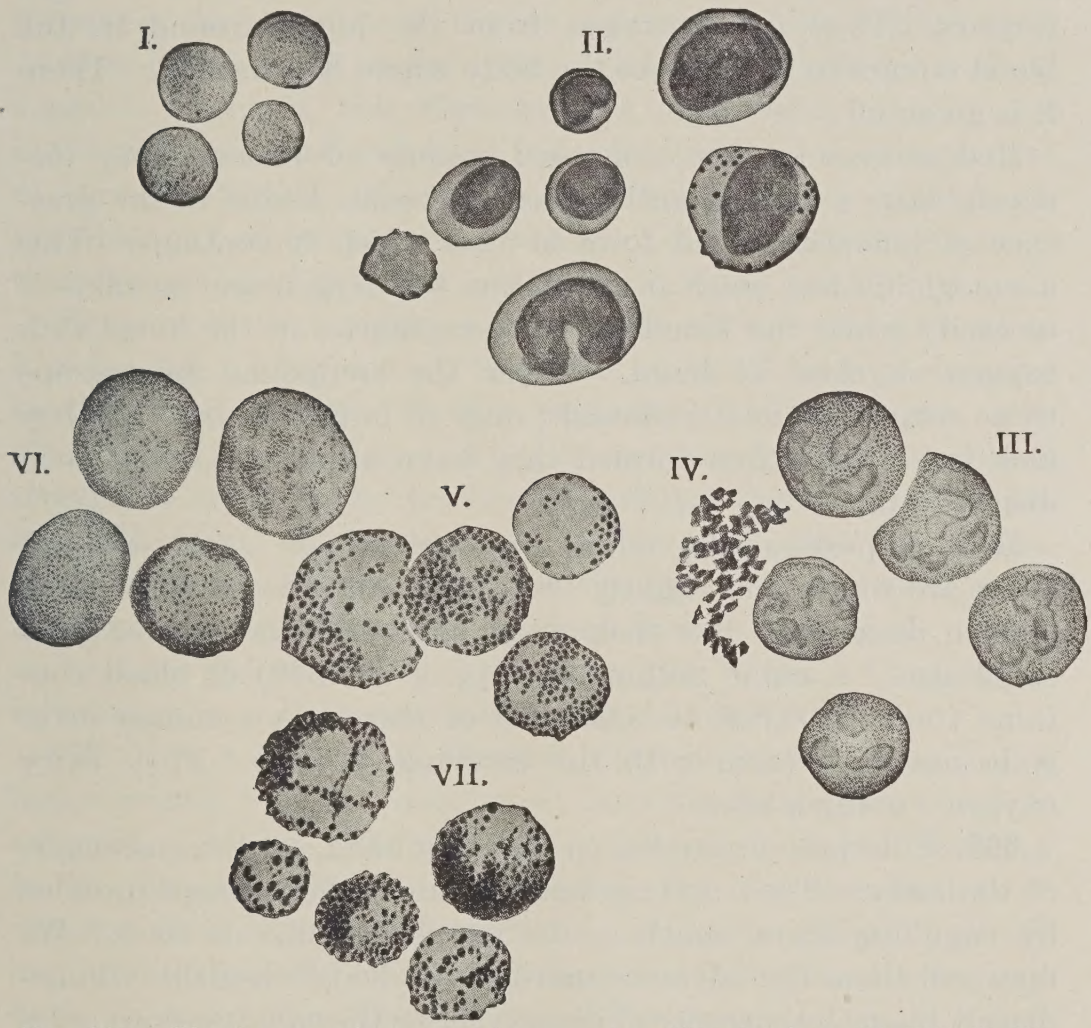


FIG. 312.—Blood corpuscles. *I*, red corpuscles; *IV*, platelets; *II*, *III*, *V*, *VI*, *VII*, various colorless corpuscles. (*Corwin and Corwin.*)

food, but when it comes **from** these areas of absorption, it contains much digested food. On its way to the kidneys the blood contains large quantities of urea, water, and salts, but much of these wastes is extracted by the kidneys, and so, after leaving the kidneys the blood continues on its way much purer than before.

We have seen that plasma is a sort of vehicle or carrier for the many substances used or given off by the different cells.

662. What the Corpuscles Do.—The work of the two kinds of corpuscles is very different. The red corpuscles are gas carriers. They carry oxygen from the lungs around in the blood stream to all parts of the body where it is needed. There it is given off.

Red corpuscles are composed mainly of haemoglobin (*he-mo-glo'-bin*) a spongy substance. Its color is due to the presence of hematin, a red form of iron which it contains. This haemoglobin has quite an attraction for oxygen and so takes it in easily while the blood is in the capillaries of the lungs with oxygen so close at hand. Under the compound microscope these corpuscles look yellowish; only in large numbers do they look red. When first formed they have a nucleus, but it soon disintegrates.

Red corpuscles are either coin-shaped or saucer-shaped. They are round and slightly less than three thousandths of an inch in diameter. But their great numbers make up for their small size. A cubic millimeter ($\frac{1}{25}$ of an inch) of blood contains from 4,500,000 to 5,000,000 of them. A common error is to associate them with the carrying of food. They carry oxygen—nothing else.

663. Colorless corpuscles, on the other hand, are the scavengers of the body. They destroy bacteria and other foreign proteins by engulfing them, much as the amœba engulfs its food. We may call them the advance guard of the body's health. Immediately upon the entrance of disease germs the colorless corpuscles attack them. One of the functions of the tonsils (spongy masses in the back of the throat) is to collect the bacteria which are in the air we breathe. These bacteria are destroyed by the colorless corpuscles which are so abundant in the tonsils. These corpuscles are larger than the red ones and have an irregular shape. Probably because of their larger size they are less numerous, there being only from 5000 to 7000 of them

in one cubic millimeter of blood. This is the equivalent of only one colorless corpuscle to every 800 to 1000 red ones.

664. The Clotting of Blood.—This is nature's way of stopping the flow from a wound. It prevents death by bleeding. The mechanism for this provision is quite interesting. There is present in the plasma at all times a substance known as **fibrinogen** (*fi-brin'-o-jen*) which means "fibrin-maker." Whenever a blood vessel is ruptured, this fibrinogen, in union with calcium and blood platelets, produces what is known as fibrin, a stringy mass of fiber-like threads, which entangles the corpuscles and forms a jelly-like clot which plugs the wound. Were it not for clotting, a mere nose-bleed would be very serious, if not fatal.

Please note that nature has to build up the clot just when it is needed. Clots cannot be stored up or allowed to circulate in the blood stream. If this happens, as it sometimes does after a surgical operation, when a clot escapes into the blood stream, it is likely to produce **embolism**[1] (*em'-bo-lizm*) which is often fatal. Perhaps you have thought out the reason. Even a small clot cannot pass through the tiny capillaries. It plugs them, shutting off the blood flow to that area. Then, as we have stated before, that area begins to die. Congestion, inflammation, and decomposition may follow.

665. How a Wound Is Healed.—The broken-down cells and other wastes together with dead bacteria form pus which is excreted. Injured cells have to be repaired and new cells have to be formed. This is accomplished by the assimilation of digested food substances from the near-by cells which, by dividing, produce growth. Gradually the new cells replace the original ones. Sometimes a kind of connective tissue is formed which can usually be distinguished by its lighter color. This we call a scar, and it may last for years.

All cuts should be sterilized to destroy any bacteria that may have entered. This is easily done by bathing the wound with any good disinfectant such as lysol or a solution of bi-chloride of mercury or any of the several good but inexpensive solutions

[1] Embolism is the closing of a blood vessel by a clot.

now on the market. A bandage will then keep out any other disease germs, until a scab is formed to protect the wound. If it is very small, a few drops of mercurochrome or iodine, completely covering it, are sufficient.

666. Lymph and Its Circulation.—Obviously it would be impossible to have enough capillaries to pass directly by all the millions of cells in the body. How then, is each of them fed? The cells of the body are bathed in a sea of lymph. Lymph is a thin, straw-colored fluid, rich in the food material and oxygen which escape from the blood capillaries. It literally surrounds the cells and fills the spaces between the tissues. Lymph has no red corpuscles but has many colorless ones. Because it is rich in food and oxygen, the cells receive these materials directly from the surrounding lymph through their thin walls. They also give out into it their wastes, such as broken-down cells, carbon dioxide, urea, and lactic acid.

It is often said that the lymph is the "middle-man" between the blood and the cells, supplying them with all their needs and taking from them their waste products. But how does the blood stream get these wastes, to excrete them? This question brings us to the circulation of the lymph.

667. How Lymph Moves.—Lymph has a circulation of its own and is not pumped around by the heart. The vast numbers of lymph spaces all over the body, connecting in a loose way with each other, are known as **lymphatics.** Those lymphatics which lie within the villi of the small intestine are called lacteals. They absorb digested fats, unite with the other lymphatics, and thus pass along this nutrient. Every movement of the muscles causes pressure on some of these lymph spaces, pushing the lymph along slightly farther. The pressure of the blood in the blood vessels also aids its flow to some extent. The lymphatic system, then, is a rather elaborate system of loosely connected spaces containing lymph. At various places, notably in the neck, are enlargements known as lymph nodes, where a large supply of colorless corpuscles is found. It is probable that colorless corpuscles are formed here. The lymphatics

finally join, forming the large thoracic duct which empties its contents into a vein that leads to the heart.

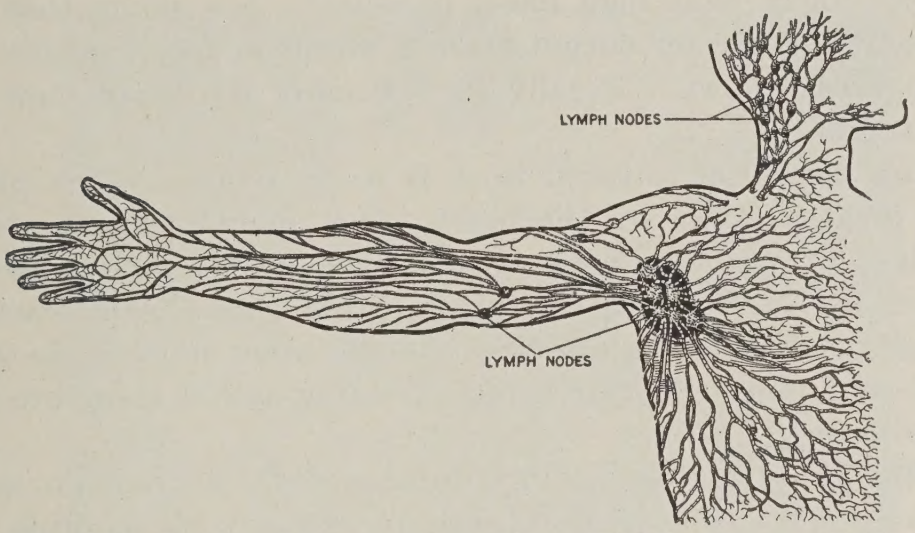


FIG. 313.—Distribution of the lymph vessels. (*Ritchie "Human Physiology," World Book Co.*)

668. General Care of the Heart and the Blood Vessels.—The heart and the blood vessels play such an important part in preserving health that their misuse often leads to serious consequences. The heart is a pump upon which the circulation of the blood depends. When the organs of one part of the body are working hard, as in the movements of the skeletal muscles during a football game, or in the action of the smooth muscles of the alimentary canal during and after a meal, the active parts receive more blood, which aids in liberating the extra energy needed.

All these various parts function normally as long as we live normal lives; but as we set a faster and faster pace of living, as we go to more places, do more work, save more time by hurrying, and almost "try to be in two places at once," our output of energy is far above normal. Let us see what happens. The system produces more blood to meet the demand. The heart beats more times per minute to deliver the blood as needed. In many cases we eat hurriedly and get less nourishment because of poorer digestion—all at just the times when our need is the

greatest for our maximum amount of energy and efficiency. Where does all this lead to? Is it any wonder that so many people today have high blood pressure? Any pump that has to deliver a greater output than it was built for, weakens and then breaks down. Usually the valves of the heart show the strain first.

Any mental or physical work is to be avoided which places too great a strain on the heart. One should learn to relax. Fatigue is more than a result; it is an index of one's endurance when not working under pressure. Regular, light exercise keeps the circulatory muscles, like the other muscles, in good firm condition. Regular habits of eating and sleeping are just as necessary.

669. Many persons eat too much meat. So too, do many persons use alcohol and tobacco to excess. These drugs act unfavorably on the circulatory system as well as on the other organs. Probably they cause the greater number of cases of arteriosclerosis (*ār tĕrĭ ō sklē rō′ sĭs*), or hardening of the arteries. In this condition, the elasticity of the arteries is diminished or lost, and their normal functioning as "shock absorbers" after each contraction of the ventricles is destroyed. This condition is serious, since the blood vessels are more easily ruptured, causing apoplexy, which is often fatal.

670. First Aid When Circulation Is Not Normal.—In cases of bleeding, the first thing to do is to stop the flow of blood. In the case of small cuts, a bandage will often accomplish this. If large blood vessels are cut, a **tourniquet** (*tōōr nĭ kĕt*), or "twister," is necessary. It should be placed between the cut and the heart, if an artery is ruptured, and beyond the cut, if blood is flowing from a vein. Can you tell why? The tourniquet should be loosened every ten minutes until a doctor can be obtained.

Often fainting is experienced when the normal supply of blood in the head becomes deficient. When unconsciousness results, the head should be lowered to allow the blood to flow into it. This treatment will usually replenish the blood supply

and remove the difficulty. If it does not, the face should be sponged with cold water.

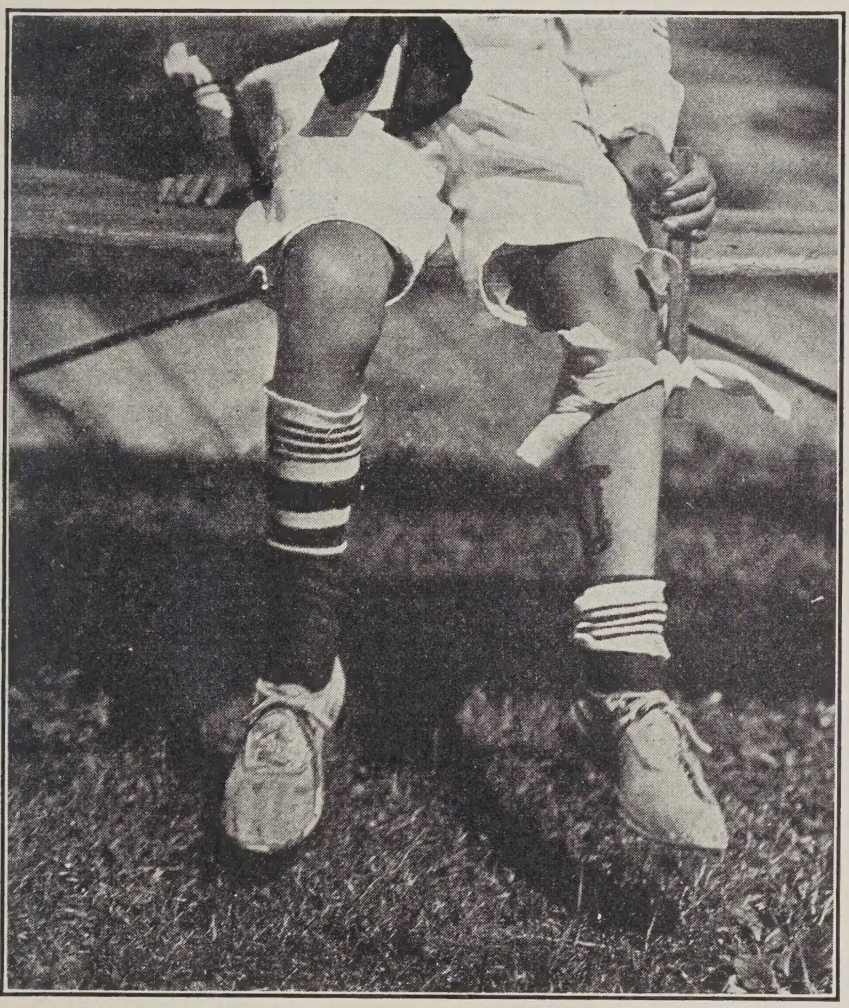


FIG. 314.—The tourniquet may be used to prevent the flow of blood from a ruptured blood vessel or to check the spreading by the blood of a poison such as snake venom. (*Atwood.*)

But in order to keep the circulation in a normal condition we should learn the way it functions, and thus be able to adjust our habits for more efficient living.

Interesting Projects

1. Using chloretone or any other anaesthetic, put a tadpole to sleep and examine the tail of the tadpole under the low power of the compound microscope. Notice the distribution of blood vessels there. Find a

tiny capillary which shows the circulation plainly, and look for corpuscles circulating in the plasma. Notice the very great number of red corpuscles which are present in the blood.

2. Examine under the high power of the microscope a prepared slide of human blood and determine the relative numbers of red and colorless corpuscles.
3. Examine the web of an anaesthetized frog's foot under the compound microscope. Is the blood circulating rapidly or slowly? Is the blood probably circulating about the same in your own body?

Review

1. Why is it necessary for the blood to circulate?
2. Does the heart ever rest? If so, when?
3. Is the composition of the blood the same in all parts of the body?
4. How does exercise affect the circulation?
5. Trace the path of carbohydrates from the small intestine to the heart.
6. Make a diagram to show the exchange of different products between the blood and the cells of the body.
7. Trace the path of blood in the human body from the left ventricle to right auricle. Name the changes occurring in the blood while following this path.
8. State the function of (*a*) the red blood corpuscles, (*b*) the plasma.
9. State one function of each of the following: lymph, fibrinogen, colorless corpuscles, capillary.
10. Trace the path taken by the blood through the human pulmonary system.

Define

artery
arteriosclerosis
aorta
assimilation
colorless corpuscles
contraction
disinfectant
dilatation
fibrinogen
glycogen
hepatic vein
lymph
lymph node
lymphatic
oxygenated blood
oxy-haemoglobin
plasma
portal circulation
pulse rate
pulmonary artery
pulmonary vein
red corpuscles
systemic circulation
tourniquet
vein
vena cava

CHAPTER XLV

OXYGEN IS NECESSARY FOR THE LIBERATION OF ENERGY WITHIN THE BODY

671. All our lives we have been breathing, yet many of us are not familiar with the mechanism which makes this process possible.

Strictly speaking, respiration and breathing are not the same, Breathing, as seen in man, is merely drawing in oxygen-laden air and forcing out the air laden with carbon dioxide, by means of the diaphragm and ribs. Respiration is a cell process. It is the taking in of oxygen and the removal of the waste gas, carbon dioxide, by the individual cells of the whole body. It is readily seen that respiration depends to a great extent on the circulatory system, for only by the help of this system can the oxygen be carried around the body to the individual cells that need it, after it has been extracted from the air in our lungs.

672. Oxygen and Carbon Dioxide.—Nearly twenty per cent of the air we breathe is oxygen gas. While this air is in the lungs, four and one half per cent of the oxygen is separated from it and absorbed into the capillaries as they ramify through the lungs.

Carbon dioxide is made up of one third carbon and two thirds oxygen (by volume). The carbon is a part of the waste from the burned fuel—food that has been oxidized in the body cells for the production of energy and for growth and repair of the tissues. This carbon dioxide is the same as the carbon dioxide gas given off from a fire, after the energy (in this case **light** and **heat**) is liberated.

673. Parts of the System. *Nostrils and Nasal Passages.*—The air enters the nostrils and passes backward through the nasal passages. These are lined with small hairs which, being moist,

collect much of the dust that is breathed in. The air is also warmed here and is thus in better condition to enter the lungs.

674. *Pharynx.*—The throat or pharynx (*far'inks*) may be compared to a railroad junction, because the course which the food takes (from the mouth to the oesophagus) crosses the course of the air (from the nasal passages to the trachea (*trā'-ke-ah*)).

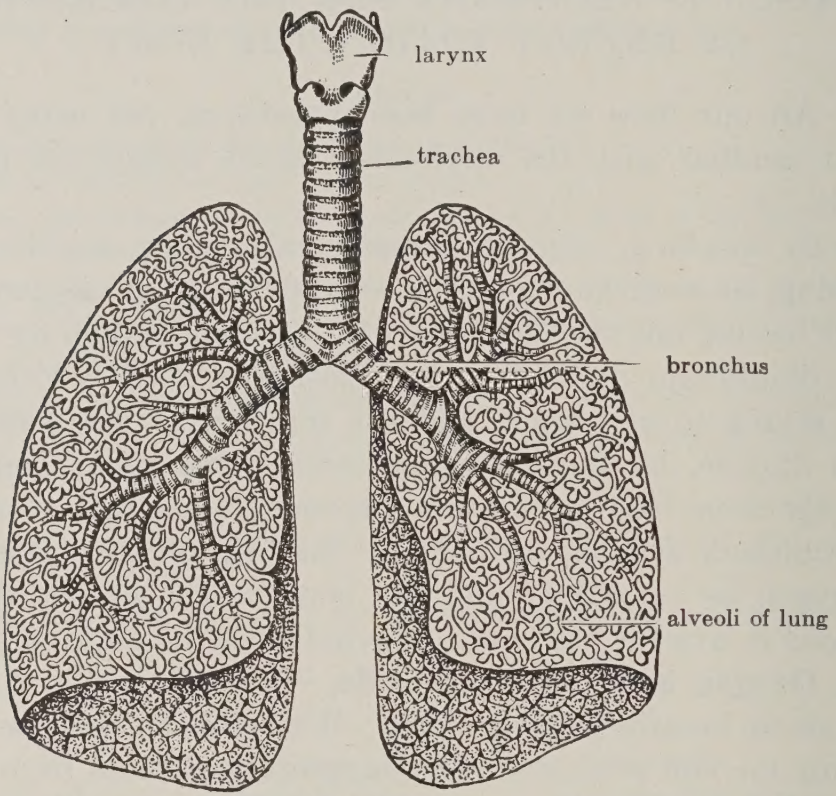


FIG. 315.—Diagram of the human respiratory tract. (*Meredith.*)

Let us see how this crossing is accomplished without admitting food into the larynx.

The accompanying Fig. 316 will show you the relationship of the different structures and openings in the throat. You will note that the oesophagus is behind the trachea, making it necessary for food and liquids to pass over the top of the larynx (a cartilaginous box containing the vocal cords). In order to prevent food from entering the trachea during its passage, a sort of trap door, the epiglottis (*ep-e-glot'-is*), which fits snugly

into the top of the larynx, is pushed down by the food. Normally it is open; therefore when the food or liquid mass has passed, it springs open again to allow air to pass through. Sometimes it fails to close quickly enough, and a bit of food or liquid gets into the larynx, or trachea. Then we cough until the substance is thus removed.

But the food might find its way up into the nasal passages instead of into the oesophagus, so that avenue must also be closed off. This is accomplished by the soft palate, which is

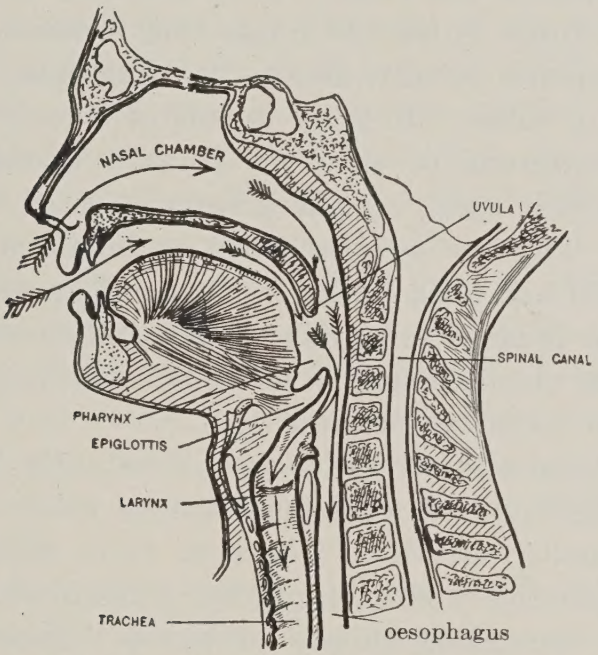


FIG. 316.—When food is swallowed the trachea is closed by the epiglottis, and the nasal passages are shut off by the soft palate. Thus the food finds a direct path into the oesophagus. (*Ritchie "Human Physiology," World Book Co.*)

pushed back by the food against the rear wall of the nasal passage. Now we see why we cannot breathe and swallow at the same time. It is just as impossible as it is for one train to pass through a junction while another train is using an intersecting track.

675. *Trachea.*—The trachea or windpipe is made fairly rigid by the cartilaginous rings which partly surround it and prevent it from collapsing when a partial vacuum is formed below. The

upper part of the trachea is enlarged to form the larynx, or voice box (often called the "Adam's apple"), an organ of speech. When we produce sounds as in talking or singing, the vocal cords are tightened and the current of air makes them vibrate much as do the reeds in a harmonica. At its lower end the trachea divides into the two **bronchi** (*bron'ki*), and these subdivide into the **bronchial tubes** which enter the lungs.

676. *The Lungs.*—The lungs are large, spongy organs, bright red in color, lying in each side of the thoracic cavity, just above and at either side of the heart. Why are they bright red? As the bronchial tubes enter the lungs they branch many times, and these branches ramify about, dividing into a very great number of tiny tubes. It is by means of these tubes that air enters the thousands of tiny air pockets known as **alveoli,** (*al-ve'-o-li*), which make up the greater part of the substance of the lungs. Thus we see that when we inhale, a vast number of these alveoli are filled with fresh air. Now since the main function of the lungs is to supply oxygen and to allow it to pass readily into the blood stream, let us see how the lungs are adapted in structure to carry out this function.

The blood from all over the body is constantly being pumped to the lungs through the pulmonary artery which divides many times into smaller arteries. These in turn, subdivide into a system of capillaries which supply the walls of the alveoli with a constantly circulating supply of blood. These walls being very thin, **the air and the blood come in very close contact,** and oxygen which has a great affinity (attraction) for haemoglobin, leaves the air by passing through the walls of the alveoli and capillaries, and unites with this material in the red corpuscles. Now the blood flows on through veins to the heart, and on around the body to supply oxygen to the thousands of cells. At the same time, carbon dioxide passes by diffusion from the capillaries into the air within the alveoli, to be exhaled as a waste gas.

677. How We Breathe.—The act of breathing, which consists of inhaling and exhaling air, is accomplished by making the air

pressure within the lungs either greater or less than that of the air outside the body.

Let us start with inhalation and assume that there is very little air in the lungs. Now since that area of the brain known as the **medulla** controls respiration, it is here that nervous impulses are started, which in turn have been caused by the accumulation of a sufficient amount of carbon dioxide in the blood. These impulses cause the involuntary movements of all the breathing muscles. One of these is the diaphragm, a large dome-shaped muscle, with its convex side toward the thoracic cavity. When the diaphragm contracts with the help of the muscles below, which pull downward on it, it is lowered, thus enlarging the thoracic cavity. The ribs, being bones, cannot of themselves expand, but they are so attached that when they are raised by the muscles of the chest wall they extend outward in such a way as to contribute to the enlargement of the thoracic cavity. The gases within the lungs now expand to occupy this larger space, and consequently become thinner or less dense. The outside air, having greater density, will flow into the lungs, if given an opportunity, and continue until the density or air pressure inside is the same as that outside. The nasal passages and trachea provide the opportunity, and the air with its necessary oxygen rushes in.

678. After the gases—oxygen and carbon dioxide—have been exchanged, the muscles relax. The diaphragm relaxes and by so doing arches up into the thoracic cavity, making it smaller. The muscles between and around the ribs cause them to move downward and inward. The air in the lungs becomes compressed; that is, its density now becomes greater than that of the air outside the body, consequently it flows out and one breathing cycle has been completed.

679. Cell Respiration.—This is the process by which the cells of the body receive their oxygen supply directly from the lymph. As the blood stream continues to flow around the body, oxygen is given out from the blood into the lymph. Now since the body cells are surrounded by lymph, it is easy to see

how this product passes directly to each cell. Cell respiration is the passage or flow of oxygen from the lymph into the individual cells and the flow of carbon dioxide from the cells back into the lymph. The accompanying diagram shows the passage of these gases to and from the cells.

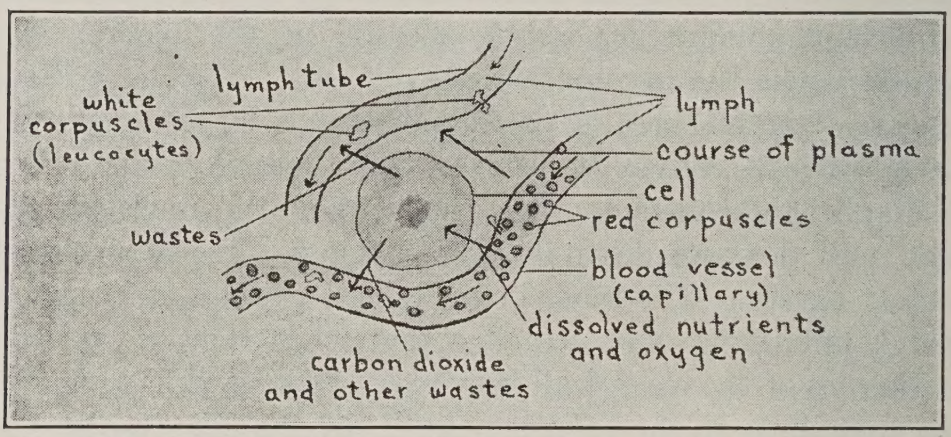


FIG. 317.—Diagram showing cell respiration, nutrition and excretion.

680. Suffocation.—Suffocation results when the oxygen supply is cut off. It may be caused by drowning, by smoke, or by poisonous gases; by being trapped in a tight enclosure, such as a vault, or by receiving a heavy charge of electricity. Although the victim is unconscious, death may often be averted by the prompt use of artificial respiration.

We hear more or less about the pulmotor (*pul-mo'-ter*), but it is less highly valued today by physicians and life-saving officials than when it first appeared, because when used by an inexperienced person, it pulls too hard, often rupturing many of the delicate lung capillaries, thus causing hemorrhages (*hem'-or-ra-jez*).

681. Schaeffer Method of Artificial Respiration.—The prone-pressure method is at present the one used by the American Red Cross, by firemen, and by police officers. In many instances the diaphragm is paralyzed, and this prone-pressure method forces it artificially into action. The method may be briefly described in the following five rules:

1. Lay victim face down, his head resting on one arm to keep dirt from being sucked into his mouth.

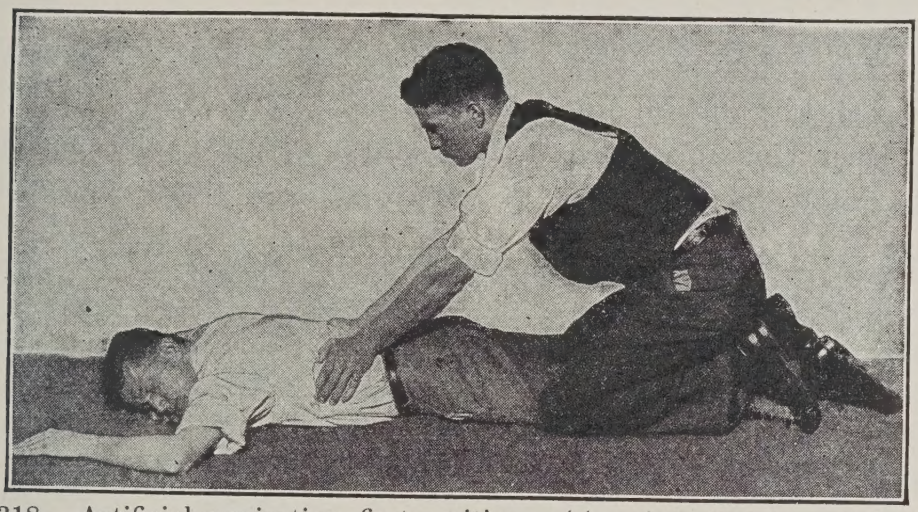


FIG. 318.—Artificial respiration, first position. (*American Red Cross "Textbook on First Aid".*)

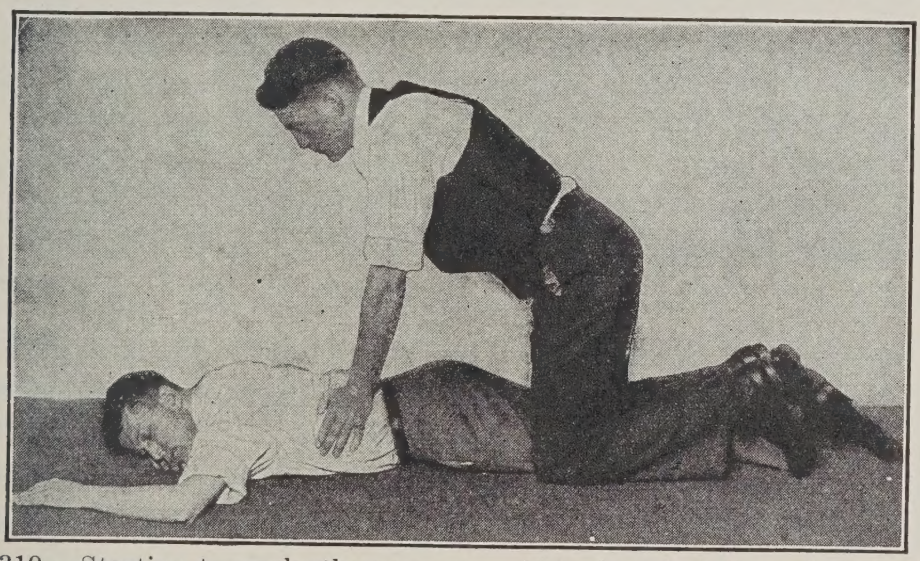


FIG. 319.—Starting to apply the pressure. (*American Red Cross "Textbook on First Aid".*)

2. Take position over victim, as shown in illustration, with one of his feet between both of yours for a support, and apply pressure slowly but firmly at base of his ribs, pushing **forward** and **downward** at the same time.

3. Keep this firm pressure on for three seconds, then quickly release it for two seconds, throwing the weight of your body off

his. (The pressure forces his diaphragm upward, crowding the air out of his lungs. The sudden release of your pressure allows the air to rush into his lungs.)

4. After relaxing for two seconds (you will need it) repeat the movements, counting aloud to help you time them.

5. Keep this up for two to four hours, or until told to stop by a physician, or until you are exhausted. If possible, summon

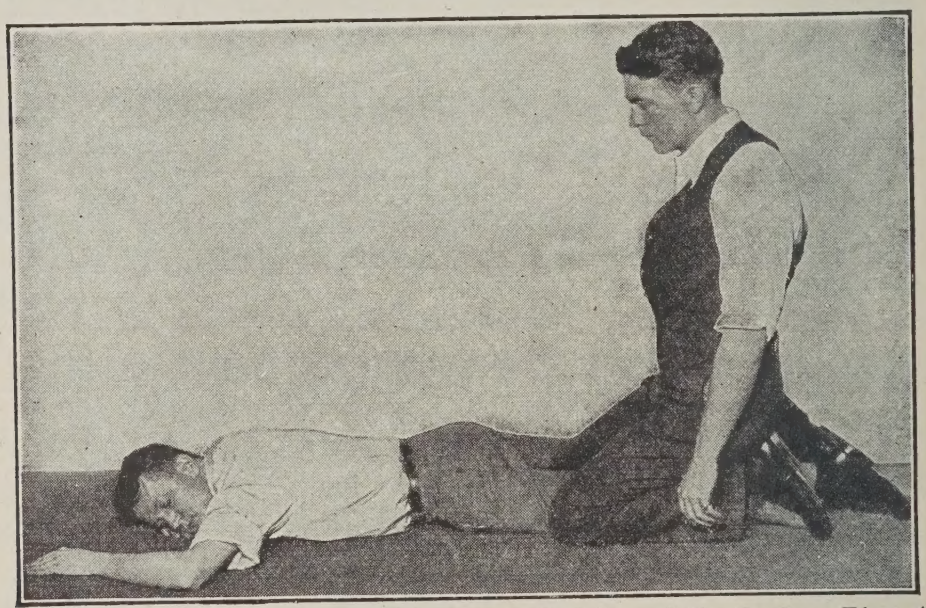


FIG. 320.—The interval of rest. (*American Red Cross "Textbook on First Aid".*)

aid, showing the person how to relieve you. Do not give up. There are many records of persons who have been saved after two or three hours of artificial respiration.

When victim recovers the use of the diaphragm, rub his limbs to stimulate circulation. Keep him warm. Give stimulants such as hot coffee, hot ginger tea, or even just hot water. To carry on artificial respiration successfully is a long, tedious, back-breaking job; but if the opportunity comes to **you** some day, it is your duty to be able to work **effectively,** because a life is in your hands.

682. Respiration and Health.—Nose breathing is the normal method of breathing and should be practiced at all times. Not only does the person who habitually breathes through his mouth

assume a somewhat idiotic expression, which is distinctly to his disadvantage, but he also injures his health.

When a person breathes through his nostrils, the air is warmed before it reaches the lungs; the nasal passages are kept moist by mucus, which collects many bacteria and much dust, as do also the moist hairs which line these passages. The adenoids and tonsils, lying at the back of the throat, are well supplied with white corpuscles which destroy bacteria and other foreign proteins. In many persons, however, these structures grow abnormally fast, becoming so large as seriously to interfere with normal nose breathing. Probably the majority of persons who breathe through their mouths do so because of these growths. In all such cases the growth should be removed by a surgeon. When tonsils and adenoids become diseased they are a menace to health and should be removed at once; but we should do well to remember that the normal adenoid or tonsil has its functions and, if healthy, does not need to be removed simply because it exists.

683. The Necessity for Ventilation.—Everyone needs fresh air and plenty of it, especially in the room used for sleeping. This does not mean that there should be a draft. Unless the room is large, an adequate supply of fresh air during the night will be obtained if the window is open a few inches at both top and bottom, the amount depending upon the severity of the weather. If the room is a large one and more than one person is sleeping in it, a better circulation of air will be obtained if one window is open at the bottom and another on a different side of the room, opened at the top. Many persons whose work keeps them away from the fresh air all day thus get the greater part of their fresh air at night.

684. Temperature and Moisture in Our Homes.—More persons today than ever before are using thermometers in their homes to aid them in regulating the temperature of the air, but in altogether too many homes this is not done, and often the air is either too warm or too cold. Between 68 and 70 degrees is a good, healthful temperature. Another factor which should not be neglected, especially in the winter months, is moisture.

Hot, dry air is not healthful; it absorbs moisture from everything, even from the nose and throat, and colds are much more easily contracted under these conditions. A temperature of 68 degrees with sufficient moisture is as comfortable on a cold day as 70 degrees of dry air. Numerous devices for supplying moisture to the air of our homes during cold weather are now easily obtainable and are not expensive.

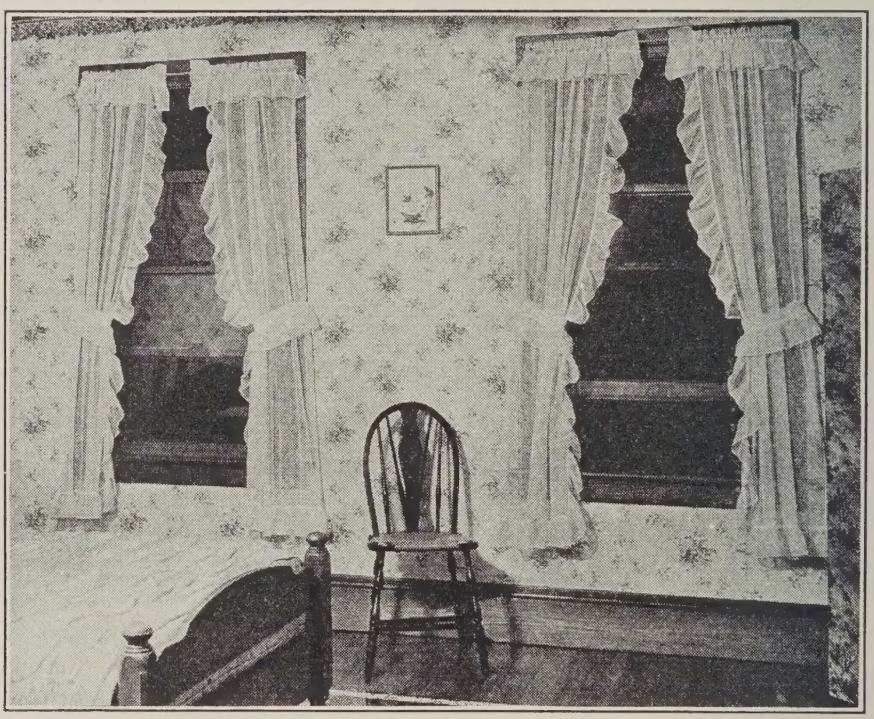


FIG. 321.—A bedroom ventilated by having one window open at the top, and the other open at the bottom. (*Courtesy, Fallot Studio.*)

685. Clothing and Health.—Public health authorities are giving much more attention to the matter of clothing today than was customary a generation ago. Proper clothing insures better health. It does not necessarily involve more expense but rather, more care. Everyone wants to wear clothing that will look good and feel well. A few general suggestions here may not be out of place.

Heavy-weight underclothing should not be worn, even in winter; it is wiser to get the protection from outer garments.

Again, too little clothing is as bad as too much. The underclothing should be changed oftener than once a week, especially during warm weather. We should avoid tight clothing such as tight belts, collars, and garters. Just enough clothing is needed to keep the body warm and comfortable at all times, varying it according to the outside temperature.

If the feet perspire freely, they should be kept dry by wearing fresh stockings daily.

Most of the weight of clothing should be supported from the shoulders rather than from the waist.

In a word, we should think and try to make our clothing do two things for us in the fullest measure: make us feel well and look good. The former is the first step toward health.

Interesting Projects

1. Learn from a fireman or life guard at some beach the changes first taking place in the human body when its supply of oxygen is shut off. Learn also how artificial respiration is applied.
2. Force ordinary air, then oxygen, through limewater. State the result. Place a glowing splinter in a bottle of oxygen. After the flame has gone out, test the gas now in the bottle, with limewater. What does it prove to be? Now blow some of the air from your lungs through limewater. Try to determine any similarity between the process going on in your own body and what you observe in the glowing splinter test.
3. Place a live mouse beneath the bell jar of an air pump. By working the handle, exhaust the supply of air within the bell jar. How has the liberation of energy by the mouse been interfered with by removing the air? Before death takes place admit air and notice what happens. What effects do you notice in the behavior of the animal?

Review

1. How is oxygen used within the cells of our body?
2. Why is not the oxygen supply of the air eventually used up by the breathing of living things?
3. What causes the outside air to pass into our lungs?
4. What is meant by *oxidation?* Tell the results of this process.
5. In tabular form compare a fish, a frog, and a man as to (*a*) organs of respiration and (*b*) breathing movements.

Define

alveoli
artificial respiration
bronchial tubes
density
diaphragm
hemorrhage
inhalation
larynx
partial vacuum
pharynx
respiration
suffocation
thoracic cavity

CHAPTER XLVI

WASTES MUST BE EXCRETED FROM THE BODY

686. As the various life processes of growth and repair, reproduction, and activity in general, go on in the individual organism, numerous waste substances are formed. Roughly, these wastes may be compared to the waste gas, carbon dioxide, and the ashes which are formed when fuel burns. In the bodies of living things, however, the actual bodies themselves wear out, so that these waste cells must also be thrown off in addition to the gases and the ashes. In the human body the blood stream not only carries nourishment to each body cell, but also collects the waste products. Upon the regular removal of these wastes from the blood stream the health of the organism depends to a great extent.

Wastes are removed from the body both by elimination and by excretion. It should be understood that elimination is the removal of indigestible food wastes which are not, and never have been, a part of the body itself. Excretion, on the other hand, is the removal of those gaseous and liquid wastes which are thrown off by the body cells into the blood stream. We should learn, therefore, just where and how these wastes are excreted in order that we may be as healthy as possible at all times.

687. The Skin.—The skin serves several functions. It is a tough, elastic covering, which protects the tissues within from sudden heat and cold as well as from exposure to innumerable injuries, germs, and poisons. It is abundantly supplied with capillaries as well as nerves which record temperature, pressure, and pain. As a heat regulator, it is a very important organ. It also excretes wastes.

The human skin, which varies in thickness from a fiftieth to an eighth of an inch, consists of two layers, the epidermis and the dermis.

688. The **epidermis** is quite thin. The cells are somewhat flattened, being subject to continual wear. As they wear off

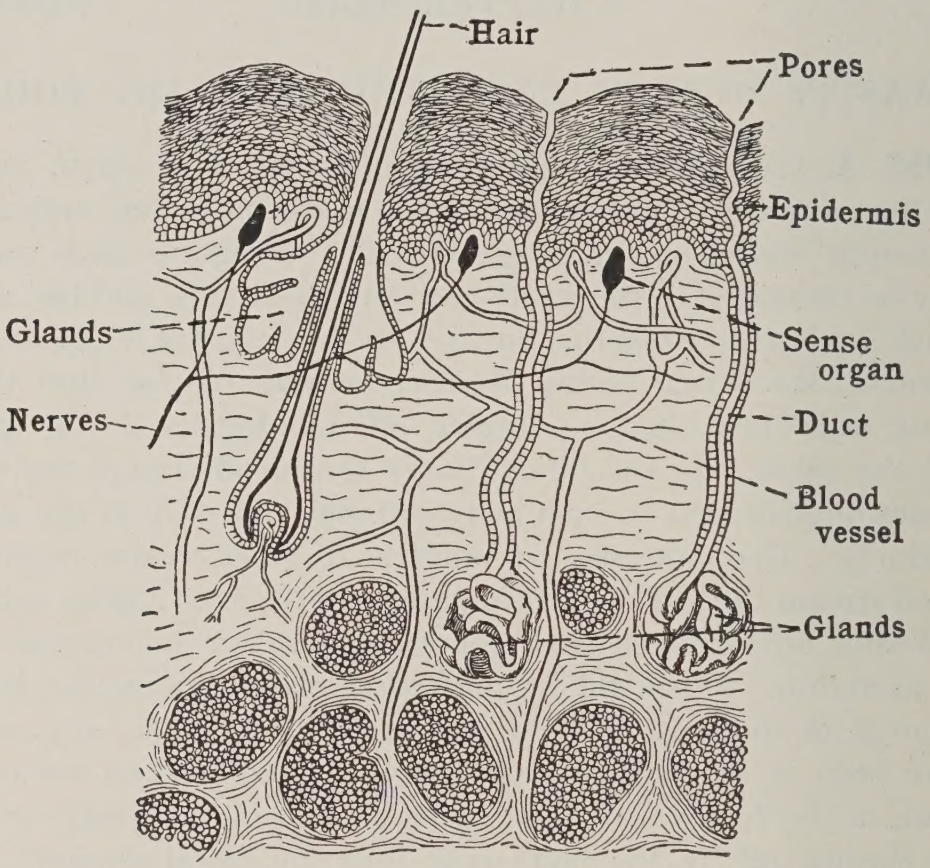


FIG. 322.—Structure of the skin. (*Atwood and Heiss.*)

they are constantly replenished from the cells of the underlying **dermis.** The epidermis contains no blood vessels nor nerves, for, like the epidermis of the upper parts of a plant, its main function is protection.

Just beneath the epidermis is a thicker layer, the dermis, which is the essential part of the skin. It is supplied with numerous tiny blood vessels and with small muscle fibers, which extend into it at frequent intervals. Here also are the hair follicles, for the greater part of the body is covered with tiny

hairs. These follicles somewhat resemble little cups, and are supplied with a small amount of fat to keep the hairs nourished. Numerous sweat glands are also present in the dermis. They resemble tiny coiled tubes which open as pores at the surface of the skin. Nerves also supply the dermis abundantly and thus greatly aid our sensitivity to touch; that is, to pressure, temperature, and pain.

These two layers of skin protect the layers of muscles which are immediately beneath, except in the case of fleshy persons, who have a layer of fatty tissue between the muscles and the skin.

FIG. 323.—Massaging the scalp keeps the hair in good condition by stimulating its supply of blood. (*Corwin and Corwin.*)

689. As mentioned above, the skin serves to regulate the temperature of the body. When the body temperature rises much above normal, which is 98.6 degrees Fahrenheit, the capillaries in and just beneath the dermis expand, thus bringing more blood to the surface to be cooled. The sweat glands become more active, secreting a greater amount of perspiration which evaporates from the surface of the body. Thus the body is cooled, since heat is always used up when any liquid evaporates. It is interesting to compare this cooling process of ours with the rapid panting of such an animal as a dog, which has no sweat glands except on the pads of its feet to aid it in keeping cool. When our body temperature falls below 98.6 degrees Fahrenheit, the capillaries contract, as do the muscles, producing "goose flesh". The amount of blood coming to the surface is thus reduced and less heat is lost.

690. But it is the function of excretion that now claims our attention. The body excretes more water than any other waste except carbon dioxide gas. On the average, the sweat glands excrete more than a quart of perspiration every twenty-four

hours. This perspiration is water in which are dissolved urea, salts, and traces of other wastes. The amount of perspiration varies according to the amount of liquid food taken, the kind of clothing worn, the temperature of the atmosphere, exercise, the presence of fear, and several other factors. If the skin is to function properly as a heat-regulating mechanism and as an organ of excretion, it should be kept clean and the pores should be free from dirt; hence the necessity for frequent baths.

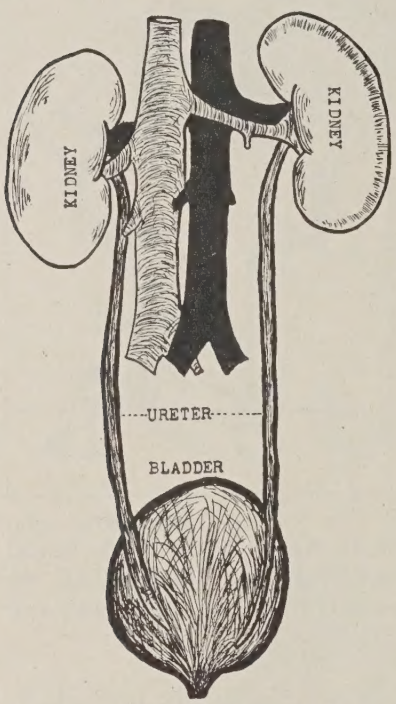


FIG. 324.—The kidneys, showing their blood supply. (*Corwin and Corwin.*)

691. The Kidneys.—Of still greater importance in excreting body wastes are the kidneys. These are two dark red, bean-shaped organs lying in the abdominal cavity on either side of the "small of the back". They are about four inches long, two and a half inches wide and three quarters of an inch thick. They are supplied with an artery which subdivides into a network of fine capillaries, thus supplying the kidneys at all times with an ample supply of blood to be purified. When the kidneys are secreting rapidly, their supply of blood is "from four to nineteen times as great as occurs in the average supply of the other organs in the systemic circulation".[1] One very important waste is urea. Urea is a complex compound formed in the liver as a result of the breaking down of certain worn-out cells and from excessive protein material. This urea, or nitrogenous waste, is transferred to the blood stream by which it is moved to the kidneys. With water, dissolved mineral salts, and certain other wastes, it then passes through the walls of the capillaries into the tubules of the kidneys. This mixture of substances, known as urine, passes by way of these countless tiny tubules into the

[1] Howell's Textbook of Physiology, p. 847. W. B. Saunders Co.

pelvis of the kidney, thence to the bladder, and on to the exterior. When the blood leaves the kidneys it is burdened with less nitrogenous waste than at any other place in its entire course throughout the body.

692. The Lungs.—Lying on either side, within the thoracic (*tho-ras'-ik*) or chest cavity, are the two lungs. These two organs remove more waste material from the body than any of the other excretory organs. They are spongy organs, composed of thousands of tiny air sacs known as **alveoli** (*al-ve'-o-li*), which are inflated with air every time we take in a deep breath, and partially collapse when we breathe out. The walls of these alveoli are very thin and are well supplied with thousands of microscopic capillaries, thus bringing the blood and the air into the closest possible relation to each other without actually mixing. It is here that the blood takes in oxygen and gives out large amounts of carbon dioxide gas, *nearly saturated with water vapor.*

693. The importance of excreting carbon dioxide and water vapor and of taking in oxygen may be realized by recalling the dozens of lives saved every year by the prompt use of artificial respiration. (See pages 465 and 466.) By this means the person, unable to breathe for himself, not only receives his supply of oxygen but excretes the waste gas with the water vapor which it contains.

694. The three main excretory organs, then, are the skin, the kidneys, and the lungs. Some persons would also include the liver and the intestines among the excretory organs. Urea, however, produced in the liver before being liberated into the blood stream, is excreted by the kidneys. The intestines serve as organs for the removal of the solid wastes, the undigested and indigestible foods (which are not and never have been a part of the body), together with digestive juices. There are also bile pigments, true excretions, which pass into the intestines, and are gotten rid of in this way. But only in this rather limited sense could we consider the intestines at all as excretory organs. The large intestine gets rid of substances it receives without mak-

ing new or different substances from them, and so are primarily considered organs of elimination rather than of excretion.

Interesting Projects

1. Breathe on a mirror held just in front of the mouth. What waste substance do you find given off in the air exhaled?
2. Remove the shoes after walking a long distance. What evidence do you find that liquids are given off through the skin?

Review

1. Why are excretory organs necessary?
2. What are the three main excretory organs?
3. From what source do these excretory organs get their products?
4. How are the different organic wastes formed within the body? Name a waste substance which might be produced in a muscle. Tell exactly how this substance would be removed (*a*) from the muscle, and (*b*) from the body.
5. What is the special function of the kidneys?
6. What other organs relieve the kidneys of a part of their work?
7. What organs excrete solutions of salts and urea? Carbon dioxide gas?

Define

bile pigments
dermis
epidermis
excretion
hair follicle
kidney
nitrogenous waste

CHAPTER XLVII

AMONG ANIMALS, THE NERVOUS SYSTEM HELPS TO MAKE THE WHOLE BODY A UNIT

695. Did you ever watch a big league pitcher throw the ball with precision, with speed, and with a graceful ease toward the

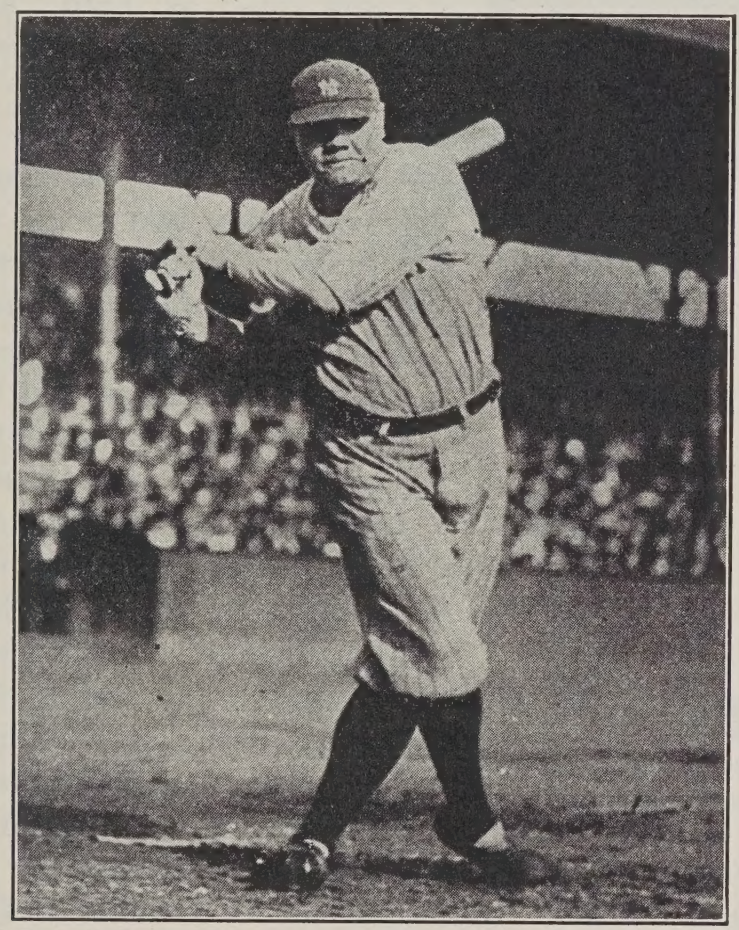


FIG. 325.—"Babe" Ruth, who has proved to be well adapted for training in baseball. (*Underwood and Underwood.*)

catcher? Did you ever watch Fritz Kreisler play the violin while you were listening to him? How easy it appears! But

how difficult it becomes when we attempt the same thing! Training makes it possible for Rosa Ponselle to sing a difficult aria in an opera with beauty and accuracy, while Babe Ruth is pulling a crowd of baseball fans to its feet with a home-run hit. But just what has happened within the body during the training process that has made such achievements possible? Why does only one person among a great many reach the pinnacle of fame while the others, striving just as hard, never get there? Let us see if we can find out.

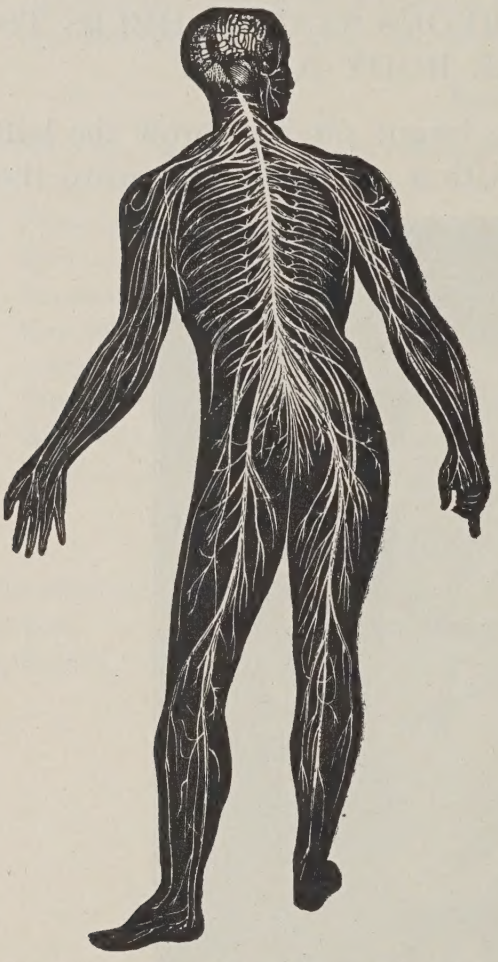


FIG. 326.—The central nervous system with its branches. (*Holmes.*)

696. The Central Nervous System.—The nervous system comprises two main divisions, the central nervous system, and the autonomic nervous system. The central nervous system consists of the brain and the spinal cord. Do you recall the brain of the frog with its six parts? There were the olfactory lobes, the cerebral hemispheres, the midbrain, the optic lobes, the cerebellum, and the medulla oblongata. The parts of the human brain are similar except that they are much more specialized. The cerebrum (cerebral hemispheres), especially, is much larger than the other parts and almost completely fills the brain case or cranium. The spinal cord extends from the medulla down through the neural canal of the vertebral column, sending out branches (nerves) at frequent intervals to the various organs. These nerves pass off in pairs between the vertebrae.

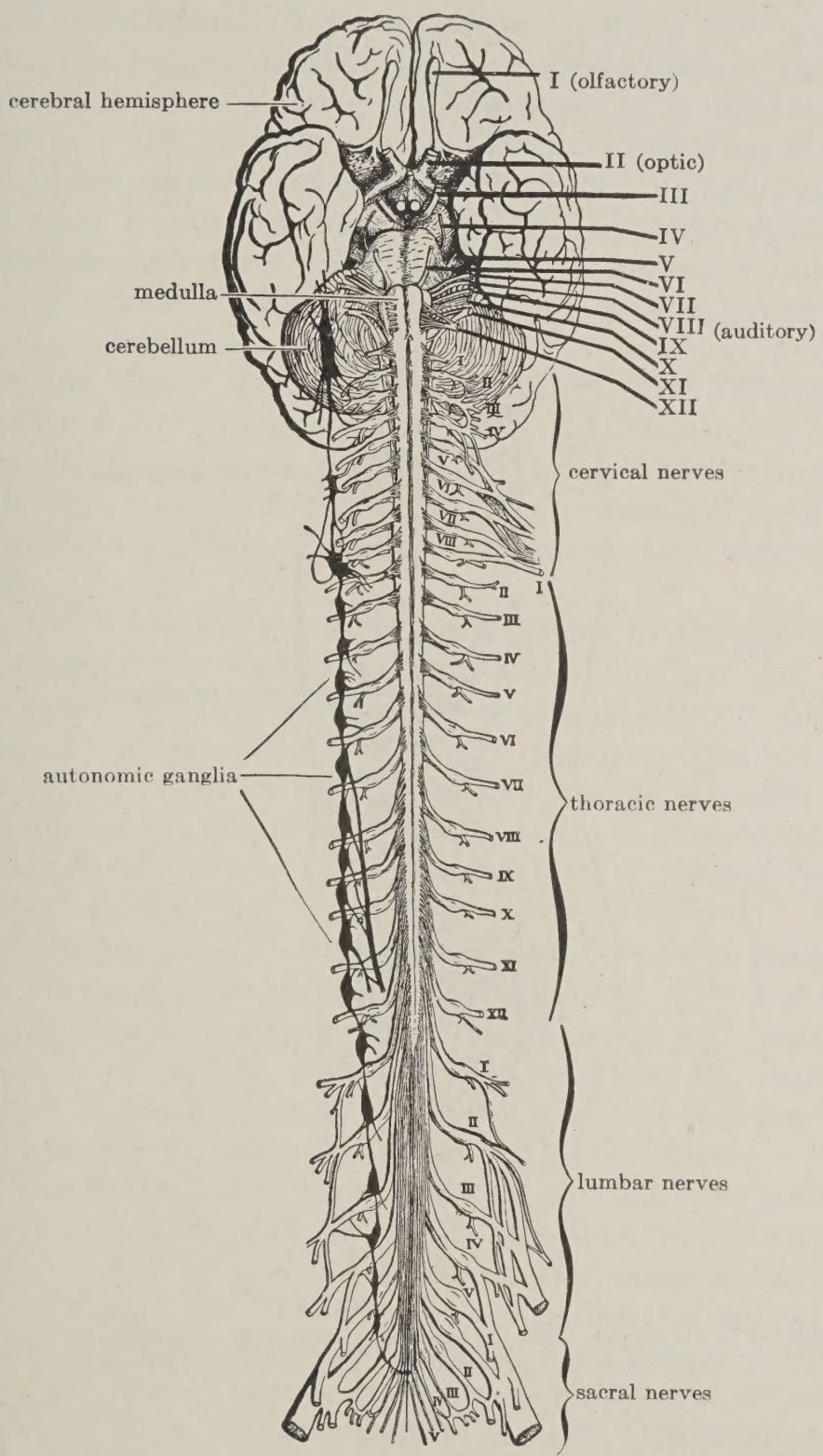


FIG. 327.—Diagram of base of brain and the spinal cord, showing the origin of the cranial nerves and spinal cord. (*Meredith.*)

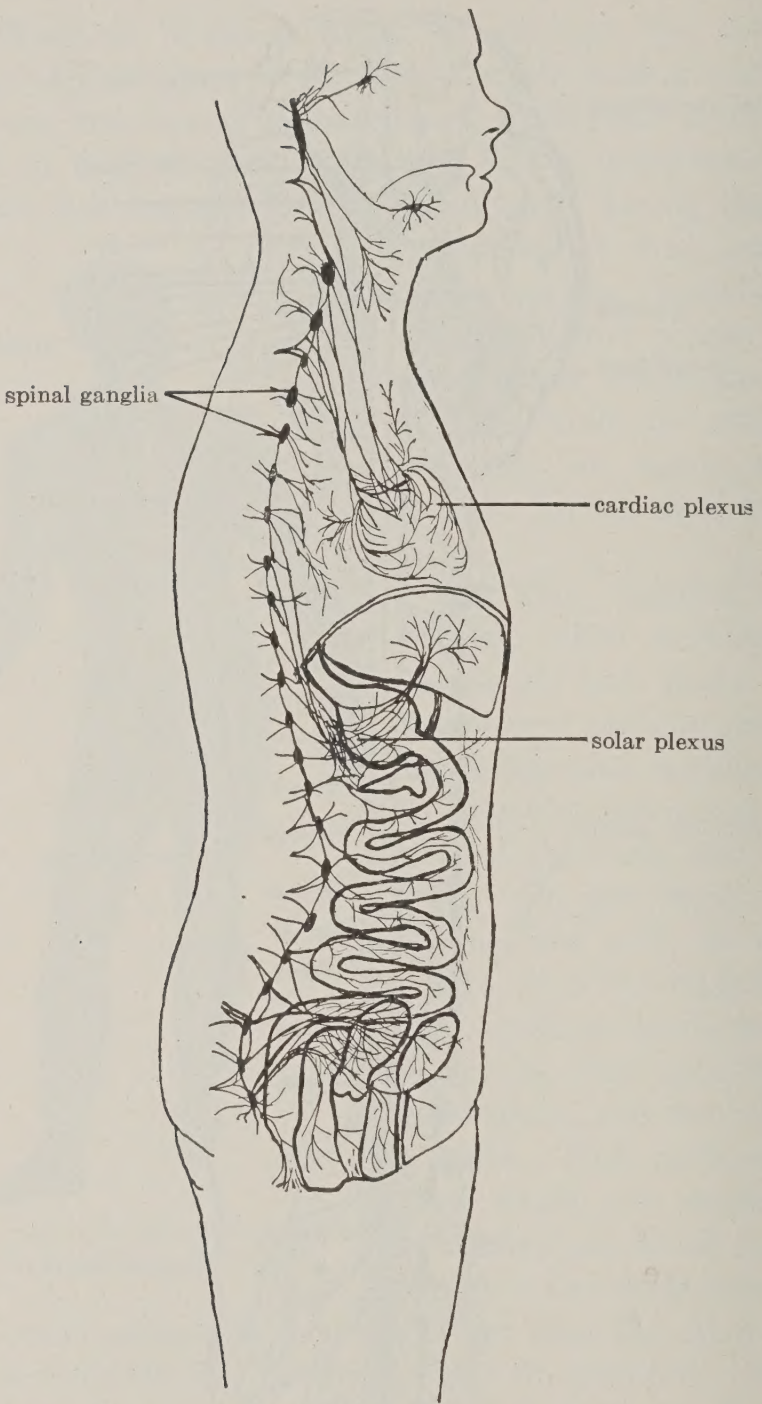


FIG. 328.—The autonomic nervous system is composed of ganglia and networks of nerves each of which is known as a plexus. (*Meredith.*)

697. The Autonomic Nervous System.—Just in front of the vertebral column and at each side of it we find a chain of ganglia (bundles of nerve cells) connected both to the spinal cord and to the organs of the trunk by means of fibers. The work of this portion of the nervous system is to control the automatic activities of these organs. As long as everything works well, the impulses necessary for a continuation of the muscular contractions of the organs are sent from this series of ganglia. Suppose, however, you had dined not wisely, but too well, and your stomach had become distended more than it ought to be. An impulse would then travel through to the spinal cord, then to the cerebrum of the brain, where you would be notified of the uncomfortable state of affairs. Let us hope that you would heed the warning of the injured organ and would decide not to overload it again.

698. This autonomic system is much affected by the emotions. When we are sad or worried, the force of the impulses from the ganglia is cut down, the heart beat is slower, digestion is slower, and there is a general depressed feeling. On the contrary, when we are happy, joyful, or excited the impulses are stronger, the heart beat is faster, blood flows faster, and there is an accompanying feeling of exhiliration. Obviously, a happy, optimistic frame of mind is healthful and is a wonderful tonic for the body. The effect of the emotions on the heart led many in former years to believe the heart to be the seat of the emotions. We find frequent references to the heart in sentimental songs and dramas. As a student of biology, you know, however, that the heart is just a specialized muscle and that it is nervous action, not the action of the heart, that indicates the various emotions.

699. The Nerve Cell.—We learned long ago that these various systems of organs are made up of cells, specialized in one way or another. And so here, we would find as the physical basis, a specialized kind of cell. The nerve cell, or **neuron** (*nu'ron*) as it is commonly called, has the cell membrane, cytoplasm, and nucleus of the typical cell. In addition it has fibrous processes or branches which extend from the main body of the cell. There are two

kinds of these processes: the **axons** (*ak'sōnz*) are long, and frequently there is just one from any one cell; the **dendrites** are short and bushy, and there may be several from a cell. The fiber is an extremely small and delicate structure, therefore it is covered with a special protective coating of fat known as the **medullary sheath** (*med'-u-lar-e shēth*). Many of these covered fibers taken together make up the white appearance of the outside of the spinal cord and the inside of the brain.

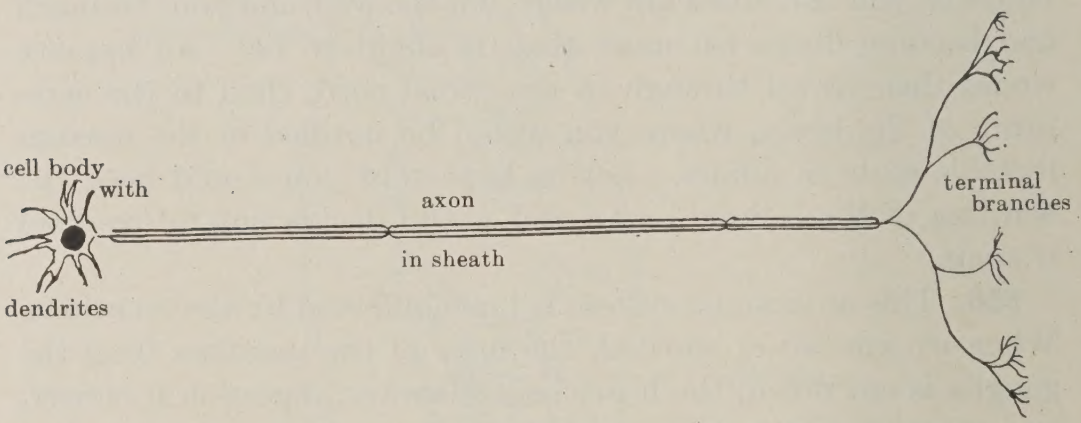


FIG. 329.—A neuron, showing cell body, dendrites, axon, and terminal branches. (*Meredith.*)

700. Cortex of the Brain.—The very thin outside covering of the cerebrum, the **cortex,** has about ninety billions of these cells. The cell bodies lack this fatty covering and are, therefore, grayish in appearance. It is in this area that our thinking is done and our voluntary activities get their inception. That is why we say a person "has a lot of gray matter"; or perhaps we say the opposite, that he "hasn't much." As a matter of fact, it is not a question of quantity but of quality. Some of the greatest men and women who ever lived have had average-sized brains. On the other hand, some persons with very large brains are not capable of using them intelligently. It is the ability of the person to associate the neurons by means of impulses that counts. An illustration will help us see what this last statement means. Suppose a child is learning to walk. A desire is set up by the impulses which have been coming in. The child has seen others

walk. The mother urges the child to walk toward her. That is, impulses have been traveling toward the brain cortex over both the auditory nerves from the ears and the optic nerves from the eyes. The child not only wishes to please its mother but also has an instinctive desire to imitate the act of walking. Eventually, impulses which will cause the proper muscles to contract find their way over the series of neurons. That is, certain

FIG. 330.—The external surface of the human brain. (*Bundy.*)

neurons have become associated in such a way that a path for nervous impulses is set up and the act is accomplished, though awkwardly at first. With repeated attempts the act becomes increasingly easy until finally it becomes habitual. When the habit is formed we need not think about it any more. We start on our way toward school in the morning, think or talk about anything else under the sun except walking, but find ourselves at school in due time after all. That is, a form of nervous activity which must first be entirely voluntary may in time become automatic.

701. Habits.—Most of our habits are of great value to us. If we had to learn all over again to dress every day there would be

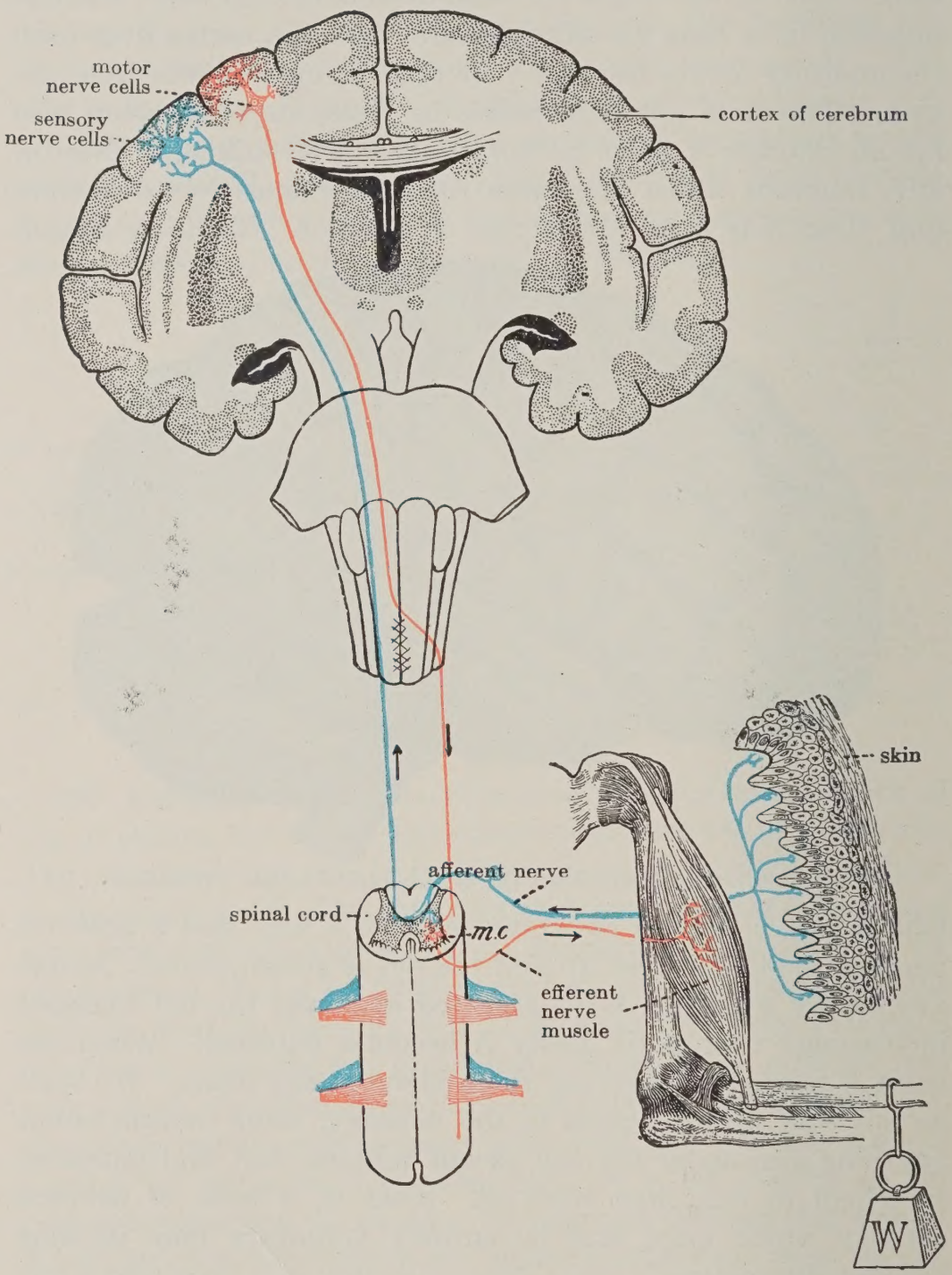


FIG. 331.—Diagram showing sensory nerve tract from skin to spinal cord, to cortex of brain (blue line); and motor nerve tract from cortex of the brain to spinal cord, to muscle (red line). (*Meredith.*)

little time for anything else. Sometimes we form a harmful habit that we should like to break. Then we are in for a struggle! Those paths for nervous impulses that have been set up have become a part of our permanent physical mechanism. We cannot destroy them any more than we can destroy the nerve structures themselves. The best way around the difficulty is to substitute something more beneficial, or less harmful, anyway. For example, suppose a person smokes cigarettes and desires to stop. It would be very difficult to break the habit by simply refraining by force of will. A better method is to substitute something which partly completes the act but is less harmful. Instead of a cigarette a piece of candy is put in the mouth. In time a new and less harmful habit has taken the place of the old one.

702. Reflex Action.—Some acts do not have to be learned. If you were standing with your back toward a hot radiator and

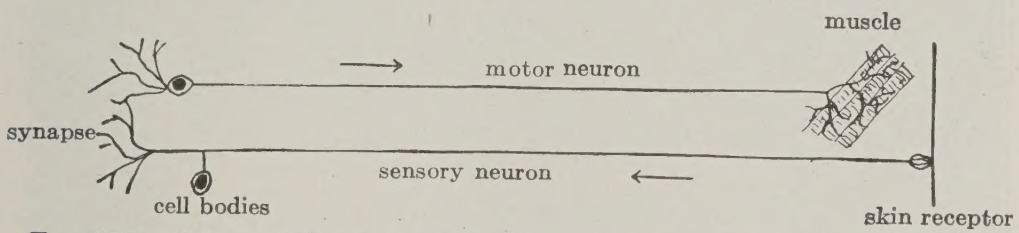


FIG. 332.—Diagram showing reflex action. The synapse is often in the spinal cord, making possible the completion of a reflex act without the use of the areas of consciousness in the brain. (*Meredith.*)

accidently touched it with your hand, the hand would be drawn away before you had time to think. This is **reflex action,** one of the most important protective processes among animals.

Reflex acts do not involve the brain except secondarily. The impulse travels inward over a sensory axon to the spinal cord. Then after passing over the dendrites of a second cell it passes over a motor axon to the muscle which will pull the hand away. In the meantime an impulse travels to the brain making us aware that something unusual has happened and we look at the hand. If it were necessary for the impulse to travel to the cerebrum and wait for a conscious decision a bad burn might result.

703. The Values of Training.—And now, referring to the topic with which we started the chapter, we see that by training we mean a continuous succession of impulses which go over certain paths of nerves and finally result in a set of habits. Just as there are individual differences among us in other ways so are there

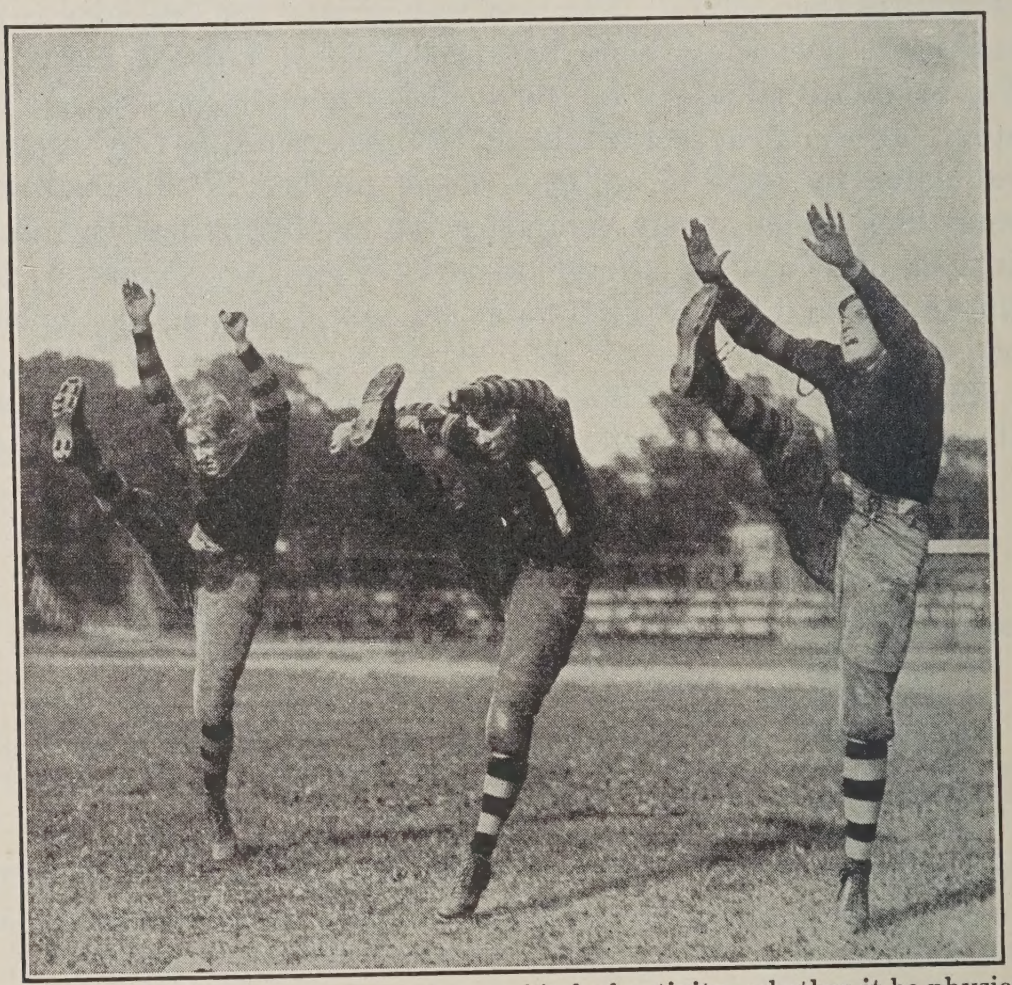


FIG. 333.—Training is necessary to any kind of activity, whether it be physical or mental, if success is to be attained. (*Meredith.*)

individual differences in our nerves. Possibly Babe Ruth could never have learned to play the violin as well as Fritz Kreisler even if he had practiced more diligently. His nervous system is not adapted for that particular kind of training. But although Kreisler may have been born with the kind of nervous system which would profit best by musical training, he did not become a violin virtuoso by merely *wishing* to become one; nor did he

arrive at his goal in a single year. Persistent practice, or in other words, sending similar impulses over the same nerve paths again and again, day after day, made him what he is. Even now he practices regularly four or five hours every day.

704. The importance of forming the right kind of habits is well expressed in the following paragraph from the book "Psychology" by William James:[1] "The hell to be endured hereafter, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time:' Well! he may not count it, and a kind Heaven may not count it; but it is counted none the less. Down among his nerve cells and fibers the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral, and authorities in the practical and scientific, spheres by so many separate acts and hours of work. Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keep faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out."

Interesting Projects

1. Dissect away the dorsal bony surface of the skull of a fish, and of a frog, or of a turtle. Make a drawing of each, and indicate the differences, and the similarities.

[1] Published by Henry Holt and Co.

2. Write an essay on the relationship between the condition of your digestive system and your outlook on life.
3. Make a list of the occasions during your life when reflex action has helped to protect you.

Review

1. To what kinds of stimuli do nerve cells respond?
2. How are reflex acts of value to us?
3. How is a habit formed?
4. How may we control our future, to some extent, by the development of proper habits?

Self-testing Exercise

The nervous system is made up of two main divisions, the (1) _____ nervous system and the (2) _____ nervous system. The brain and the spinal cord make up the (3) _____ nervous system. The parts of the brain of the frog are (4) _____, (5) _____, (6) _____, (7) _____, (8) _____, and (9) _____. In man a chain of ganglia on each side of the spinal cord and just in front of it make up the (10) _____, nervous system. This system mostly controls the automatic activities of the organs of the (11) _____. The nerve cell or (12) _____ often has two kinds of processes, or fibers, the shorter bushy ones are known as the (13) _____, the longer one is the (14) _____. The fibers are often covered with a protective coating of fat called the (15) _____.

An act which has been learned so thoroughly that no conscious thought is required for its completion is known as a (16) _____. Certain automatic activities designed to protect the body which do not have to be learned are known as (17) _____.

Define

central nervous system
cerebellum
cerebral hemispheres
cranium
medulla oblongata
midbrain
neural canal
olfactory lobes
optic lobes
spinal cord
autonomic nervous system
vertebral column

UNIT XII

CERTAIN ORGANS AND PROCESSES CONTRIBUTE TO THE POSITION OF MAN AS THE DOMINANT KIND OF ORGANISM

CHAPTER XLVIII

MENTAL HYGIENE IS AS IMPORTANT AS PHYSICAL HYGIENE

705. If you were asked to think of persons, not of your own family, whom you most admired, and were also asked to name those personal qualities which made them worthy of your admiration, probably your answer would include such characteristics as honesty, courage, and friendliness. Perhaps your list might not include at all such qualities as the ability to make or to keep money, to dress well, or to be socially prominent, although these social attributes are of admitted value. Colonel Lindbergh has won universal esteem because of his high character as well as for his ability to fly.

706. Keeping Mental Balance.—People, whether prominent in the day's news or not, who are successful at the business of living, have one invariable characteristic that we can all imitate with profit. It is the ability to keep a mental serenity by judging accurately which of life's events are of great importance and which of little importance. No living man or woman, prince or pauper, can have the details of his life always ordered to his liking. A day without at least a few petty annoyances is rare indeed. But the person who is mentally well balanced gives us the appearance of seldom being annoyed because each obstacle of minor importance receives but minor consideration. So many

persons spend valuable energy struggling against trifles unworthy of so much attention! They constantly form and live in a "tempest in a teapot."

707. The Physical Effect of Emotions.—We learned earlier, when studying digestion and the glands of internal secretion, how

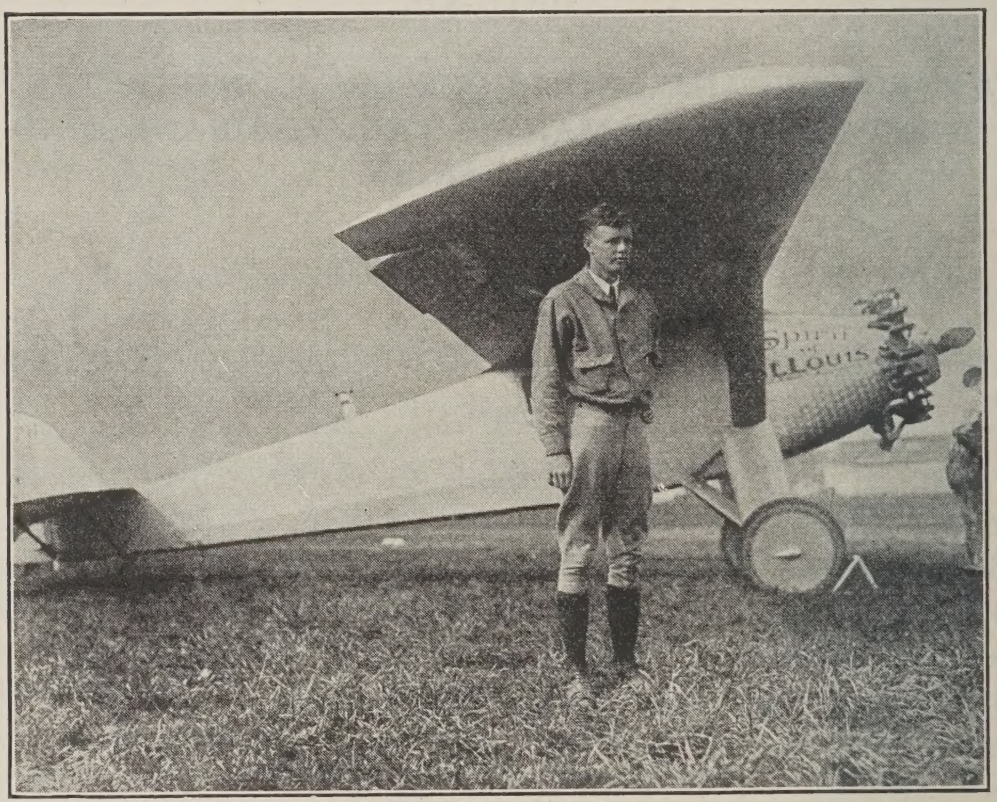


FIG. 334.—Colonel Lindbergh, a well-balanced personality. (*Underwood and Underwood.*)

the emotions affect us physically. Constant worry retards the digestive process and brings on indigestion. This in turn makes it more difficult to be happy. Fear and anger stimulate a greater discharge of stored glycogen from the liver into the blood stream, thus reducing the amount of material usually reserved for emergency use. In other words, the emotions of greed, envy, hate, worry, or grief have a definite physical effect, which in time may bring about serious organic defects. And we can often do so much to prevent these emotions from harming us!

708. Adjusting Our Habits of Living.—Our methods of living are a serious handicap in preserving mental health, especially if

we live in the city. The constant noise, sometimes deafening, the hustle, the nervous strain that accompanies the feeling that a certain amount must be accomplished within a given time, all take their toll of our strength. Tests by psychologists have shown that noises cause fear responses even when we understand what the noises are and when we are too busy consciously to notice them. Each of these takes its toll of nervous energy.

FIG. 335.—Swimming is an excellent form of recreation. (*Meredith.*)

Hurried lunches of improperly chosen foods, lack of exercise, insufficient fresh air and sunshine all contribute to the destructive process. And fatigue of the nerves, like fatigue of the muscles, results in the accumulation of definite toxins, or poisons, which may not be eliminated when we crowd further activities into the period better devoted to rest.

Living under pressure and imperfect hygienic conditions becomes such a habit that a person sometimes believes it is impossible to change this method of living. Physicians may have to remind us that if we do not choose to devise some means of decreasing the load, Nature herself will take a hand and force an

involuntary retirement through nervous breakdown or organic disease.

709. Mental Attitudes.—As a student of biology, you already know that an attitude of mind is a mental habit. We can form a habit of looking at the world as a pretty poor place in which to live by always looking at it in that way, just as we can develop a habit of smoking too many cigarettes. And we can change a wrong attitude of mind exactly as we can change a harmful habit—by consciously and persistently substituting something better in its place. Difficult? Yes, it is, but nothing in the world makes better returns on the investment of time and effort.

FIG. 336.—Helen Keller, whose achievements are a source of great inspiration to handicapped persons everywhere. (*Courtesy of the American Institute for the Blind.*)

710. Our School Work.—Many pupils get a wrong attitude toward school work. Lessons are long and hard. Certain courses turn out to be different from what we expected, and we may find them uninteresting. The goal is seemingly so far away. How much better off seem the boys and girls who are earning their own money and who have the independence that goes with it! When one is free to choose, it is hard to stay in school under such conditions. But it is worth while. The habit of doing the harder thing is of value in itself. Any vocational adviser can demonstrate to you that each day in school is a definite investment, worth more to you, in dollars alone, than you could earn without the school training.

711. That Intelligence Test.—Another source of discouragement in school life for many of us is the intelligence test. The pupil who fails to do as well as he would like to, feels like a lame

man in a race—very much handicapped. But let us not take these tests too seriously. They indicate certain things of value to the teacher. Intelligence, as indicated by them is without doubt valuable, but if unaccompanied by such qualities as integrity, honesty, and persistence of purpose, they may lead a person to a prison cell rather than to a position of influence. Remember Aesop's fable of the hare and the tortoise.

712. Other Causes of Unbalance.—Mental distress often results from other causes. One may feel that one's clothing is not as good as that of another. There may be social slights, cheating that goes undetected, and unjust discriminations. All of these sources of mental discomfort demand some sort of adjustment on our part. If we remember that such annoyances seem much more serious to the individual concerned than to anyone else, and that people are usually too busy with their own affairs to notice unless we call their attention to them, then it becomes easier to give them only their proper value and reduce the feeling of inferiority or unjustness to some extent.

713. Obtaining Help from Others.—Within the past few years, rapid advances have been made in the development of methods for relieving the mental distress due to worry, confusion, and other causes. Physicians, psychologists, and social workers have kept careful records of a vast number of cases, and from these records certain general principles have been formulated which make it possible for a trained and skillful mental hygienist to be helpful in preventing harmful effects. Some of the larger universities now employ such specialists to aid students whose work may be affected by mental stress. Many cities have clinics to serve all the people of the community in a similar way.

The fact that serious and permanent harm may result from worry, anger, grief, hate, and similar emotions when long continued, should convince us that we ought to seek any available relief from mental distress just as we go to see a physician for advice concerning physical disorders.

714. Keeping a Healthy Mind.—And now let us conclude with some of the ideas which we may be able to put to work for us.

Mental health is so closely related to physical health that we must maintain our physical well being by eating wholesome food, and by getting plenty of fresh air, sleep, sunshine, and exercise.

We must try to get into the kind of work that we like best and for which we are best suited. This is not always easy and is sometimes impossible. It is important, however. Nothing is more depressing than to work continuously at a disagreeable task with the feeling that one is completely unsuited for it.

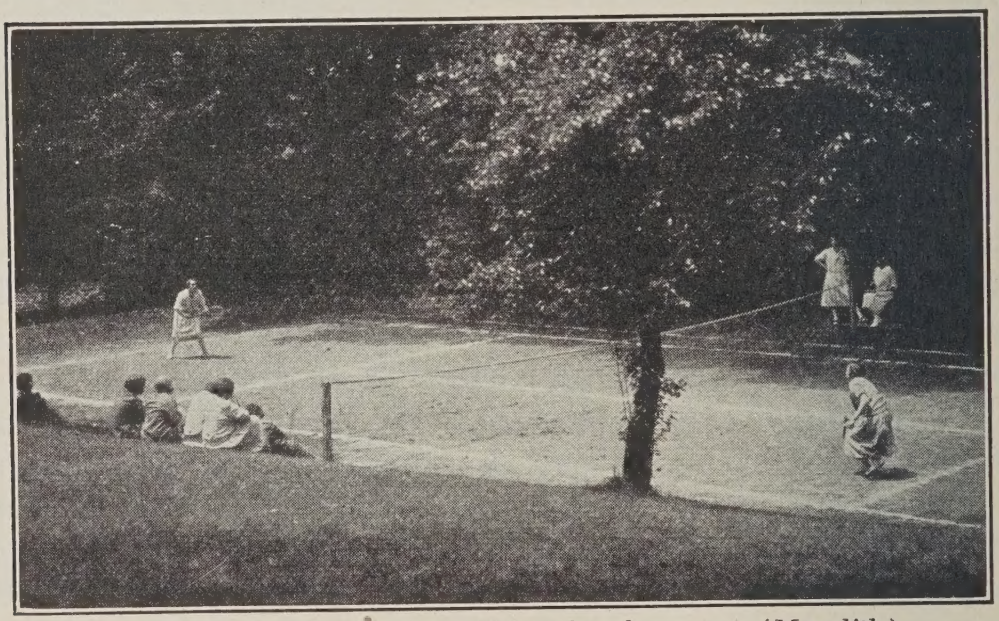


FIG. 337.—Tennis develops skill and endurance. (*Meredith.*)

A popular song during the World War advised people to turn the dark clouds inside out so that the silver lining would show. This advice is valuable in peace times, too. It is not difficult to find others who are worse off than we are, no matter what predicament may arise.

Nothing is more healthful, mentally, than to find a hobby, different in nature from our regular work and so interesting to us that we can lose ourselves in it.

Last but not least in importance we need to develop and maintain friendships by being friendly ourselves, and by observing the Golden Rule.

Interesting Projects

1. Choose two homework tasks of equal difficulty. Complete one task in a room with the radio turned on, or where there is conversation; then do the second task where there is little or no distraction. Compare the results and write a paragraph in your notebook giving your conclusions.
2. Assume that without a high school education it would be possible to earn an average salary of $1500 a year over a period of forty years. A person with a high school training usually earns about twenty per cent more than one without such an advantage. Using these values as a basis, compute the value of each year of a high school course.
3. Make a list of other values that may be obtained from high school training.

Review

1. Which kinds of mental attitudes are most desirable?
2. How do desirable mental attitudes assist in maintaining good health or in improving poor health?
3. How may our habits of living affect our mental attitudes?
4. How can mental attitudes be modified?
5. To whom may we go for help from mental discomfort?
6. What rules for physical health will help us maintain mental health?

Define

emotion **mental attitude** **mental hygiene** **nervous breakdown** **psychologist**

CHAPTER XLIX

THE SENSE ORGANS ARE OUR AGENTS FOR CONTACT WITH THE WORLD ABOUT US

715. It is impossible to imagine what sensations we received when, as babies, we first opened dazed and uncertain eyes on

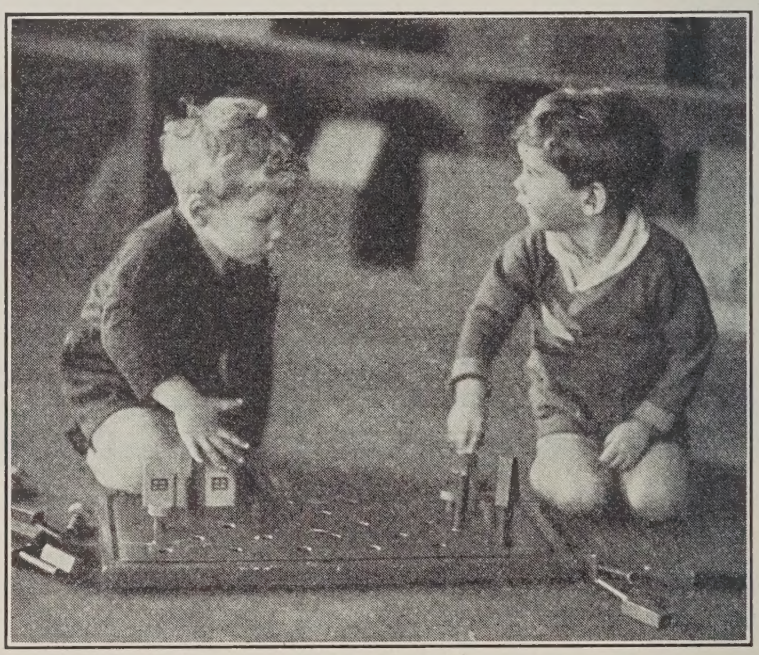


FIG. 338.—Learning new facts or methods requires time and patience. (*Courtesy of Child Development Institute, Columbia University.*)

a world so entirely new to us. The impulses were received by a brain that had no background of knowledge. How could it interpret them? It is no wonder that babies seem bewildered! We, as adults, would be in a similar predicament, placed in a new world with everything equally strange and different.

Gradually the sense organs of the baby begin to function better. Certain sights, such as the mother's face, are seen so frequently

that the images are separated from the confused mass of sense perceptions and begin to have meaning. The same thing is true of sounds received by the ear and the impulses received from the other sense organs. Gradually, more and more sense perceptions assume a meaning, and the background of knowledge continues to increase all through our conscious life. Strictly speaking, it is unnecessary to go to school to learn things. We are constantly learning whether we will or not. The great function of the school is to direct this process of learning along useful and necessary lines.

716. The Eye.—Our eyes are our most precious possessions. We gain more of our knowledge of the world about us by these organs than by any other kind of sense organ. The eye has often been compared to a camera. Let us see what a comparison of the two reveals.

717. You will note from the diagram of a camera that its principal parts are a shutter for controlling the amount of light admitted, a lens for directing the light, and a substance capable of being affected in a definite way by light. This substance has been placed on a celluloid film or on a glass plate. All these are placed within a box which will admit light only through the opening controlled by the shutter. Rays of light which are reflected from the different parts of an object are directed by the lens so that they fall on the substance made sensitive to light. Thus an image is formed which resembles the object.

718. The eye is a rounded box. The outside is covered with a thick white coat of fibrous tissue, the **sclerotic** (*skle-rot'-ik*) coat. Just inside this is a layer of tissue richly supplied with blood vessels, the **choroid** (*ko'roid*) layer. And lining it on the inside there is a thin layer of nerve endings that are sensitive to light stimuli. This layer is known as the **retina** (*ret'-in-ah*). The nerve endings are the ends of the fibers which make up the **optic nerve.** The stimuli are conducted over this nerve to the brain where they are interpreted. The brain and eyes are dependent upon each other. The eye is capable of only receiving light stimuli; there must be a brain to interpret their meaning. But the brain itself can-

not pick up these light stimuli; it must have these especially adapted structures to do that.

719. A bulging section at the front of the eyeball is transparent for admitting light. This is the **cornea.** A thin, round curtain with a round hole in the center is able to open or to nearly close the opening known as the **pupil.** The curtain is the **iris,** and it works very much as the shutter of the camera does except that it is automatic in its action, being controlled by the intensity or

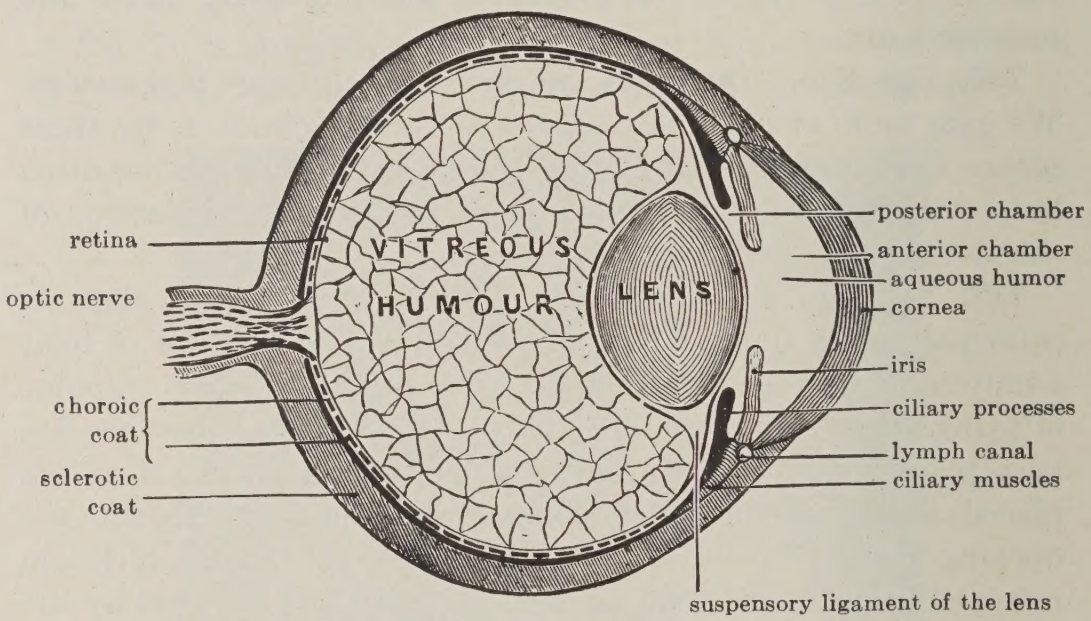


FIG. 339.—Diagram of vertical section of eye. (*Meredith.*)

brightness of the light. Just behind the iris and pupil is the **crystalline** (*kris'tal-in*) lens. This looks much like a simple magnifying lens. It is convex on both sides (see Figure 343). The **ciliary** (*sil'-e-ar-e*) muscles at the edges control its shape, making it more or less convex, according to the need. Between this lens and the cornea there is a thin, watery liquid, the **aqueous** (*a'-kwe-us*) **humor,** which maintains the roundness of the cornea. Filling the space between the lens and the retina the **vitreous** (*vit'-re-us*) **humor** gives roundness to the eye as a whole. Muscles attached to the outside are arranged so that they work together in causing the eyes to turn in the same direction at the same time.

720. Although a general comparison between the eye and a camera is possible, the eye is infinitely more efficient. All through life when the eyes are functioning, we see a continuous motion picture of passing events, in color, clearly, and without frequent stops to change reels. And in many cases the mechanism works faithfully all through life without need of constant care.

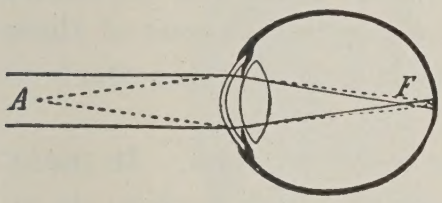


FIG. 340.

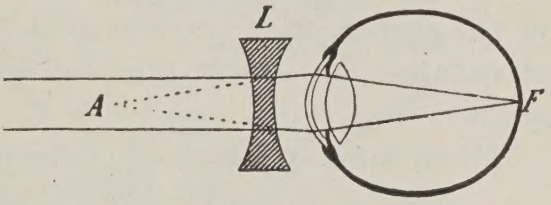


FIG. 341.

FIGS. 340 and 341.—Diagram to illustrate nearsightedness (myopia) and the use of a reducing lens to correct it. Parallel rays of light focus at *F*. When the lens *L* is used the rays focus on the retina. (*Atwood and Heiss.*)

721. Defects of the Eye.—The most common defects in vision are caused by defects in the structure of the eye itself. If the distance between the cornea and retina is so short that the image tends to form back of the retina (See Figs. 342 and 343),

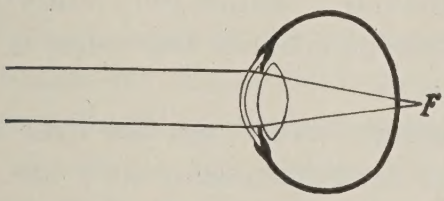


FIG. 342.

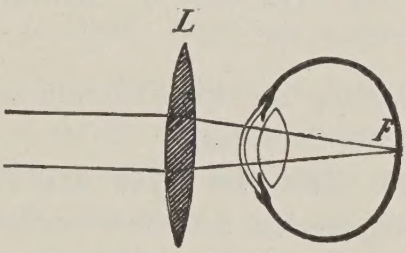


FIG. 343.

FIGS. 342 and 343.—Diagram to illustrate far sightedness (hypermetropia) and the use of an enlarging lens to correct it. The lens *L* causes the focus *F* to fall on the retina. (*Atwood and Heiss.*)

the person is said to be far-sighted. That is, objects at a distance may be seen clearly, while those near at hand cannot be brought into focus. Old people are often afflicted with the same trouble when the lens can no longer be contracted sufficiently. The newspaper or magazine sometimes has to be held at arm's length to be read.

When the opposite condition is present, that is, when the distance between the cornea and the retina is so long that the image tends to fall in front of the retina (See Figs. 340 and 341), the person is said to be nearsighted. When the eyes are in this condition, objects at a distance look blurred, while printed material has to be brought close to the eyes.

722. Astigmatism (*as-tig'-mat-izm*) is an abnormal curvature of the cornea or of the lens. It may occur in any part of these structures, or either one as a whole may be imperfect in shape.

These three types of eye defects are very common. In many persons the imperfection is so slight that the handicap is never realized. All three of these conditions can be "corrected" by lenses. It is unfortunate that many children are unjustly accused of laziness or have poor scholarship records when at small cost the handicap which causes the trouble could be removed. Adults may suffer with headache, due to eyestrain needlessly, because the cause is now really understood.

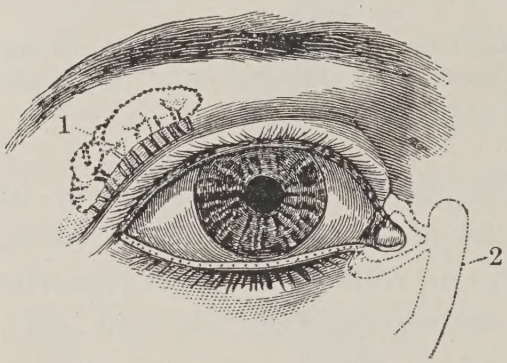


FIG. 344.—The eye. 1, lachrymal gland; 2, tear duct. (*Holmes.*)

723. How the Eyes Are Protected.—Although the eyes have a conspicuous position because of their function, they are well protected. The surrounding bones receive many of the blows that fall on that portion of the face. The eyebrows and eyelashes prevent perspiration from entering, and the lids close quickly by reflex action when danger approaches. The occasional winking of the lids keeps the exposed surfaces moist by means of a liquid secreted by glands just above the eyes.

724. The Ear.—When an object vibrates in the air, waves are set up, something like the ripples in the water after a stone is thrown in. The number of waves, which

determine the pitch of the sound, depends on how fast the object vibrates.

725. The outer ear, the part which may readily be seen, is adapted for collecting these waves and conducting them to a

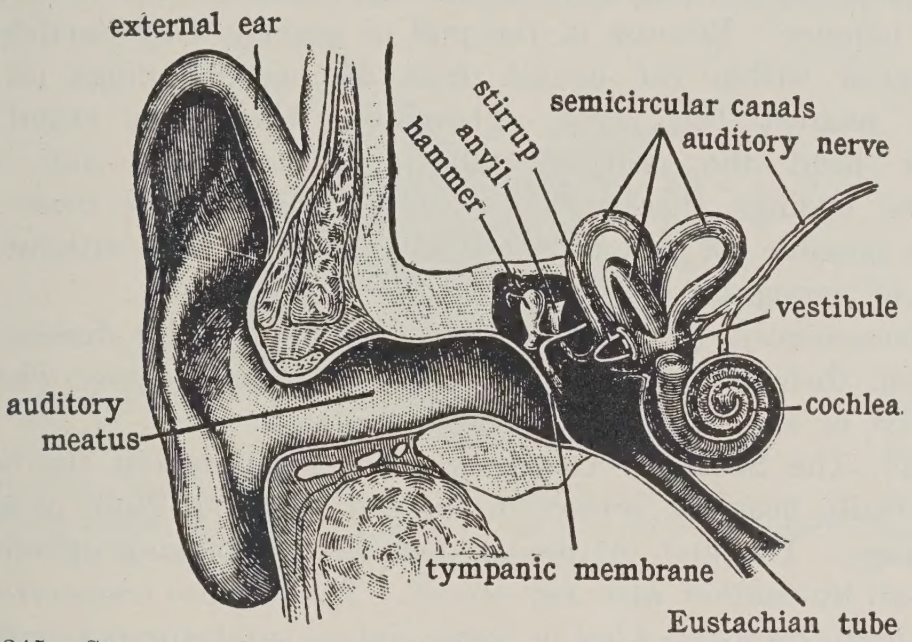


FIG. 345.—Structure of the ear and the semi-circular canals. (*Atwood and Heiss.*)

canal which leads to the ear drum. The vibrations set up in this membrane are transferred through a series of small bones and pass to a liquid in the inner ear. This liquid surrounds a structure, known as the **cochlea** (*kok'le-ah*), in which are the nerve endings of the **auditory nerve.** The vibrations set up in the ear drum by the sound waves pass through the liquid, are picked up by the nerve endings, and are transferred as sound impulses to the brain where they are interpreted. The chamber of the middle ear is closed off from the canal of the outer ear by the ear drum, or **tympanic membrane,** and from the inner ear by a membranous window touched by one of the small bones. It is connected with the throat by a tube, the **Eustachian** (*u-sta'-ke-an*) **tube.** This allows air to enter from the throat, thus equalizing the pressure on both sides of the drum and permitting a complete

vibration. In this way the drum is protected from any violent vibrations which might rupture it.

726. The Organ of Equilibrium.—Situated close to the inner ear and connected to the brain by a branch of the auditory nerve are three canals, semi-circular in shape, which enable us to keep our balance. Because of the pull of gravity, tiny particles of material within the canals press on nerve endings on the side nearest the earth. Therefore, when you stand on your head the particles fall to the opposite side. The nerve endings there transfer the stimuli to the brain and it is possible for you to determine your position without the aid of eyesight.

Occasionally these structures are affected by disease. A person then finds it very difficult to maintain balance when it is dark or when the eyes are closed.

727. The Sense of Touch.—Scattered throughout the body, especially near the surface of the skin, are four kinds of nerve endings. The first of these is adapted for picking up stimuli caused by contact with any object. The impulse transferred to the brain from this kind of nerve ending is interpreted as being hard or soft, rough or smooth, wet or dry, or combinations of these. The second kind of nerve ending picks up stimuli which we interpret as pain. A third kind is stimulated only by objects warmer than the body itself, and the fourth type of ending is stimulated by objects colder than the body temperature. Experiments with a very fine needle in the middle of the back, where these endings are least numerous, have shown that each kind of nerve ending is specific; that is, it transmits only one kind of stimulus. For example, the needle, if heated slightly, is interpreted as being cold when it touches a cold-detecting nerve ending.

728. The Senses of Taste and Smell.—The organs of taste, or the papillae on the tongue, have been described in an earlier chapter. To complete our group we need only to include here the sense of taste which is intimately related to the sense of smell with nerve endings in the nasal cavities.

Certain soluble substances present in the air as vapors are able to affect the nasal nerve endings and to be interpreted as odors.

729. Many foods give off odors, and it is the odor passing up the nasal cavities from the throat more than the effect on the

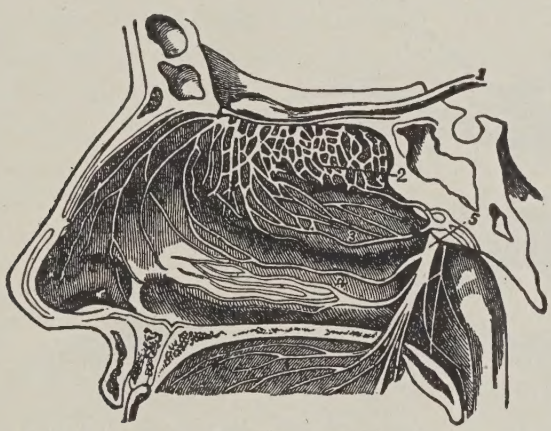


FIG. 346.—View of the interior of the nasal chamber to show the olfactory (smelling) organ. The olfactory nerve (1) comes in from above and its branches are distributed as shown in (2). (*Atwood and Heiss.*)

nerve endings in the papillae that give flavor to such foods as cheese and onions.

730. Irritability in Other Organisms.—The ability of sense organs to respond to stimuli is based on the principle that all protoplasm is irritable. Among plants we have noted how leaves and flowers are affected by light and by a certain degree of warmth. Roots direct their course toward water and a food supply. The simplest animals, the protozoa, react in a definite way to light. Higher forms, such as worms, are capable of picking up light stimuli on any part of the skin although they have no definite light-receiving organs or eyes. Among the highest of the invertebrates, such as the insects, specialized nerve endings in true eye structures are present, and doubtless form some sort of image.

Just how much some of the lower invertebrates can hear is uncertain. Many of them do react to sound waves which probably affect only the skin. In the grasshopper we noted a sound-

receiving organ located in the first segment of the abdomen; and recent experiments seem to indicate that insects make and receive sounds so high-pitched that the human ear cannot detect them at all.

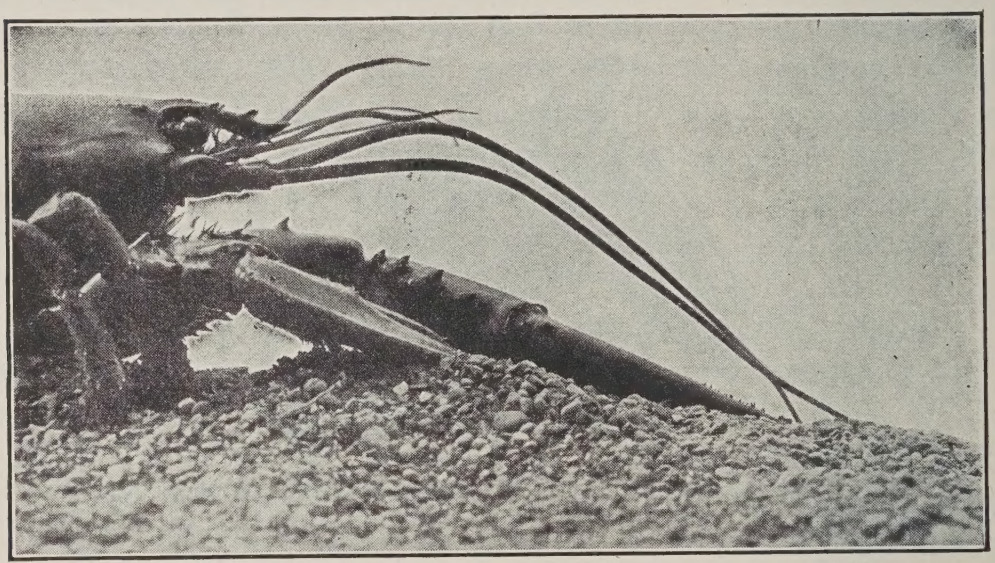


FIG. 347.—The sense organs of the lobster. The antennae are delicate organs of touch. (*Atwood.*)

731. The greater complexity of the brain as an interpreting organ, and the more elaborate sense organs, indicate that the vertebrates receive a greater variety of stimuli than the invertebrates, and thus more detailed information from their surroundings. These stimuli provide a greater background of knowledge which, together with the ability to reason, gives the highest of the animals, man, his dominant position.

Interesting Projects

1. Have some one feed you small portions of (*a*) onion, (*b*) apple, (*c*) coffee, (*d*) cheese, and (*e*) potato while you are blindfolded. Shut off the sense of smell by holding your nose so that no odors are detected. How many of the foods can you distinguish?
2. Read the story of the life of Helen Keller. In your notebook write a brief review of her remarkable achievements.

3. In a tabular form, list the kinds of stimuli which affect each kind of sense organ.

Review

1. What are the similarities between the human eye and a camera?
2. What are the causes of nearsightedness, farsightedness, and astigmatism?
3. In what different ways are the eyes protected?
4. What are the parts of the ear?
5. How do external sound waves set up the impulses which are interpreted by the brain as sound?
6. How does the organ of equilibrium help us keep our balance?
7. What are the four kinds of nerve endings associated with the sense of touch? What is the function of each one?
8. How are the senses of taste and smell related? Of what value to us is this relationship?
9. Why are the vertebrates able to receive a greater variety of stimuli than the invertebrates can receive?
10. What is the relationship between this ability to receive more stimuli, and the position of dominance which the vertebrates hold?

Self-testing Exercise

The outside of the eye is covered with a thick white coat, the (1) _____ layer. Just inside is the (2) _____ layer. The innermost layer, the (3) _____ is sensitive to light stimuli. The impulses which are set up reach the brain by means of the (4) _____ nerve. The transparent front of the eye is the (5) _____. A thin, round curtain, often colored brown or blue, is known as the (6) _____. An opening through the center of this curtain is the (7) _____. In back of the curtain is the (8) _____ lens. This lens is controlled by the (9) _____ muscles. Filling the space between the lens and the outside layer is the (10) _____ humor. Abnormal curvature of a transparent structure of the eye results in a defect known as (11) _____. Eyestrain due to defects in eye structure may often be relieved by the use of properly fitted (12) _____.

Sound waves cause the (13) _____ membrane to vibrate. These vibrations are transferred to the (14) _____ in which are the endings of the (15) _____ nerve.

Nerve endings in the skin are adapted for picking up four kinds of stimuli which are interpreted in the brain as (16) _____, (17) _____, (18) _____, or (19) _____.

Vertebrates are considered to be higher than the invertebrates principally because of their more highly developed (20) _____ systems.

Define

aqueous humor
astigmatism
auditory nerve
choroid layer
ciliary muscle
cochlea
cornea
crystalline lens
Eustachian tube
far sightedness
focus
iris
near sightedness
organ of equilibrium
papillae
pupil
retina
sclerotic coat
semicircular canal
sense organ
tympanic membrane
vitreous humor

CHAPTER L

THE DUCTLESS GLANDS HELP TO MAKE THE ORGANISM A UNIT

732. In our study of the digestive system we learned about the liver, the gastric glands, and other digestive glands, and found

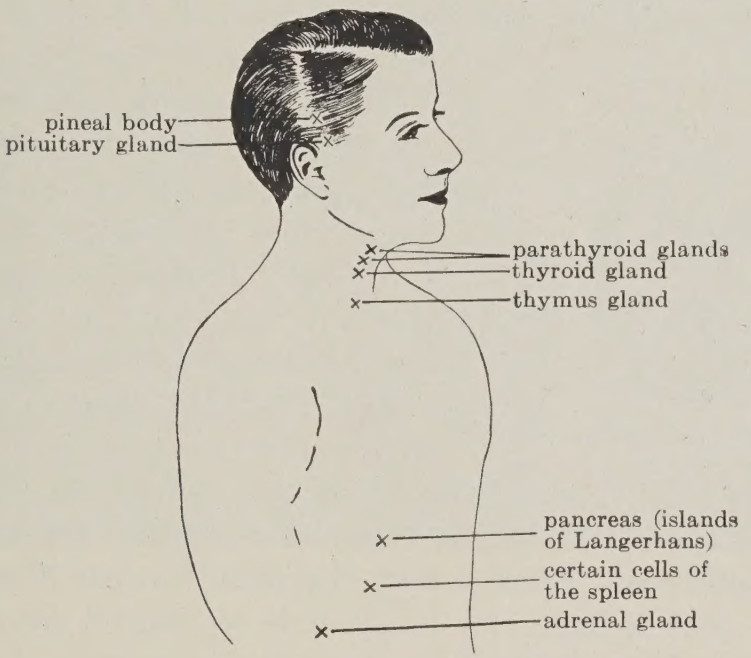


FIG. 348.—The location of certain endocrine glands.

that each of them pours out its secretion into the alimentary canal through a small tube or duct. Much attention is being centered today upon another type of gland, the endocrine (*en′dō krīn*) or ductless glands, those small glands located in several parts of the body which have a much greater influence on our development and health than was formerly supposed.

Many body functions are believed to be chemically regulated and controlled by the **hormones** (*hor′-mōns*), the fluids secreted

by the ductless glands. These glands, as their name signifies, have no ducts, but give out their secretions directly into the blood stream, which carries them around as **chemical messengers** to those tissues whose functions they control. Some of these hormones increase and others decrease the activity of certain parts of the body. Recent progress in research work to find, in more detail, the reactions produced by hormones within the body promises much help for persons who have glandular disturbances. We now know that deficient amounts of some hormones can often be supplied by including extractions of similar glands from sheep or other animals in one's daily diet. There are still many glandular reactions, however, that we do not understand sufficiently to control.

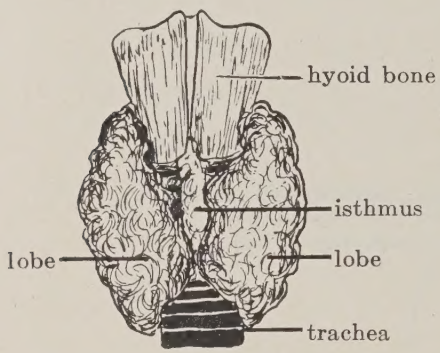


FIG. 349.—The thyroid glands.

The principal ductless glands are the **thyroid, thymus, adrenal** (*ad-re'-nal*), **pituitary** (*pit-u'-it-a-re*) **gland, parathyroid** (*para thi'-roid*), **pineal** (*pin'-e-al*), **islands of Langerhans** (*lahng'er hahns*) of the pancreas, and the **glands of reproduction.**

733. Thyroid Gland.—The thyroid is a fairly large, U-shaped group of glands located at the front of the throat just below the "Adam's apple", or larynx. Its blood supply comes through many capillaries. Its secretion, thyroxin, consists of more than fifty per cent iodine. Its function is to control development, mental as well as physical.

734. An insufficient supply of thyroxin, produced when the gland has degenerated or is not functioning properly, causes a general slowing down in metabolism due to deficient oxidation of food. This condition, if continued over a sufficiently long period, results in **cretinism** (*cre'tin izm*). Cretinism is a disease characterized by slow physical and mental development, the main symptoms of which are stunted growth, the "cretinic" face with flattened nose, thickened lips and tongue, harsh skin, and more

or less advanced idiocy. If the patient is fed extract of sheep's thyroid, a marked improvement generally results.[1]

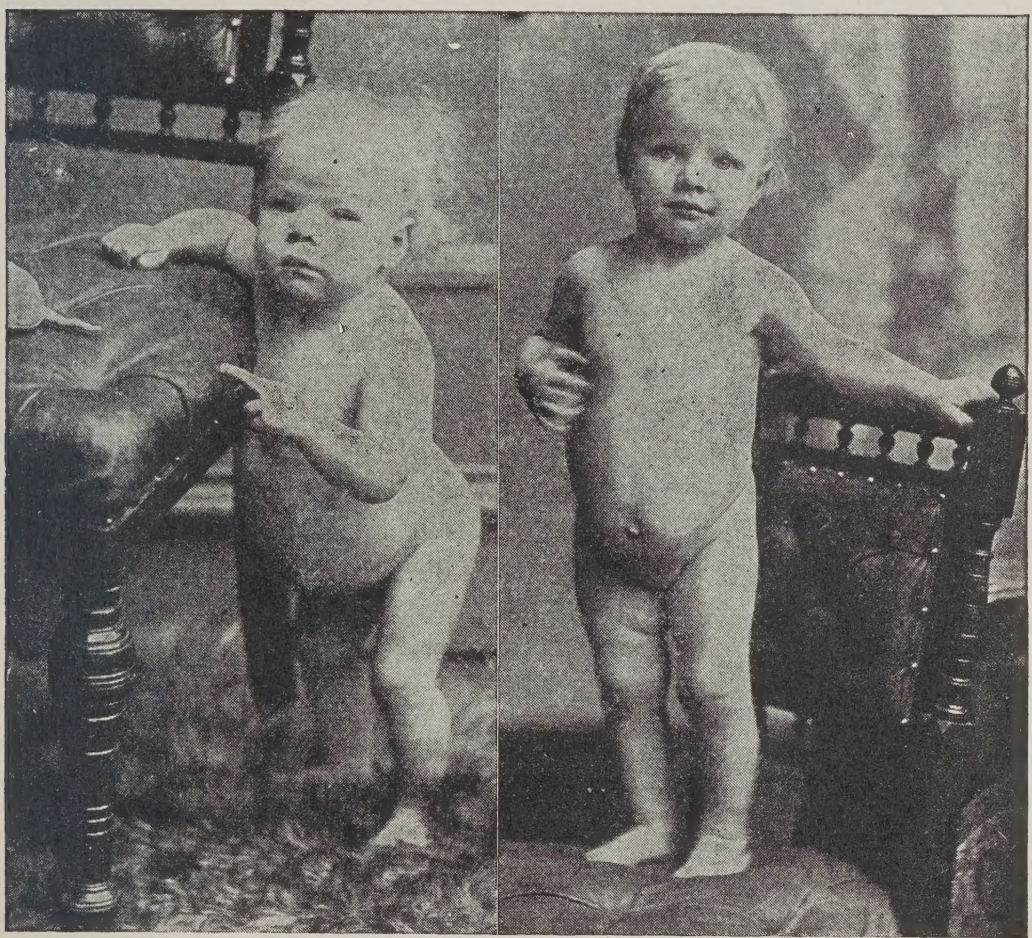


FIG. 350.—A cretin (*A*) before, and (*B*) after treatment with thyroid extract. (*Meredith.*)

735. An over-supply of thyroxin produces the opposite effect. Metabolism is increased and the respiration and pulse rate

[1] In some areas of the country, such as the Great Lakes region, which are far removed from the ocean and consequently lacking in iodine supply, another type of goiter—enlargement of the thyroid gland—called **endemic** (*en dem'ik*) **goiter** results. Here the gland is trying to overcome the iodine shortage by itself growing larger so as to have a greater secretion. Introduction of certain forms of iodine usually remedies the trouble. In the Great Lakes region iodine is introduced into the public water supply, so as to prevent the population as a whole from endemic goiter.

become faster. Nervousness is generally apparent and the person becomes restless. This disease, called **exophthalmic** (*ek sof-thal'-mik*) **goiter** (because of the accompanying protrusion of the eyeballs), produces a large growth in the neck. Medical attention is required for either insufficient or excessive supply of thyroxin.

736. The Parathyroids.—Near the thyroid glands are two pairs of very small glands, the parathyroids. At present we know little about them except that they regulate the quantity of calcium in the blood.[1]

737. Thymus Gland.—The thymus, located in the chest cavity behind the breast bone or sternum, is believed to play an important part in the early growth of children. It begins to diminish in size at about two years of age, and when the period of adolescence has been reached it has practically disappeared. This has led some scientists to believe that the thymus has a retarding influence on sex development.

738. Pituitary Gland.—Like the thymus, the pituitary gland is very small and its functions are not well known. It lies in two parts or lobes at the base of the brain. One lobe secretes a hormone which stimulates body growth, while the other one secretes a hormone which stimulates the action of smooth muscle. Animals from which this gland has been removed fail to grow, and remain as pigmies. On the other hand, examination of giants often shows that this gland has developed to an abnormal degree.

739. Adrenal Glands.—Just anterior to the kidneys lie the adrenal glands. Their secretion, **adrenin** (*ad re'nin*), which is well known, has a valuable use in medicine. Normally the adrenals secrete an extra quantity of their hormones into the blood stream in times of fear, anger, and excitement, causing

[1] It may be of interest to teachers and certain students to know that definite amounts of calcium (lime) salts are essential to the body in furnishing materials for the growth of the skeleton, in sustaining the contractions of the heart, in aiding the clotting of blood, and in maintaining the irritability of muscles and nerves.

the liver to release glycogen (*gli'ko jen*), which is readily assimilated, thus instantly releasing "new strength" just when it is

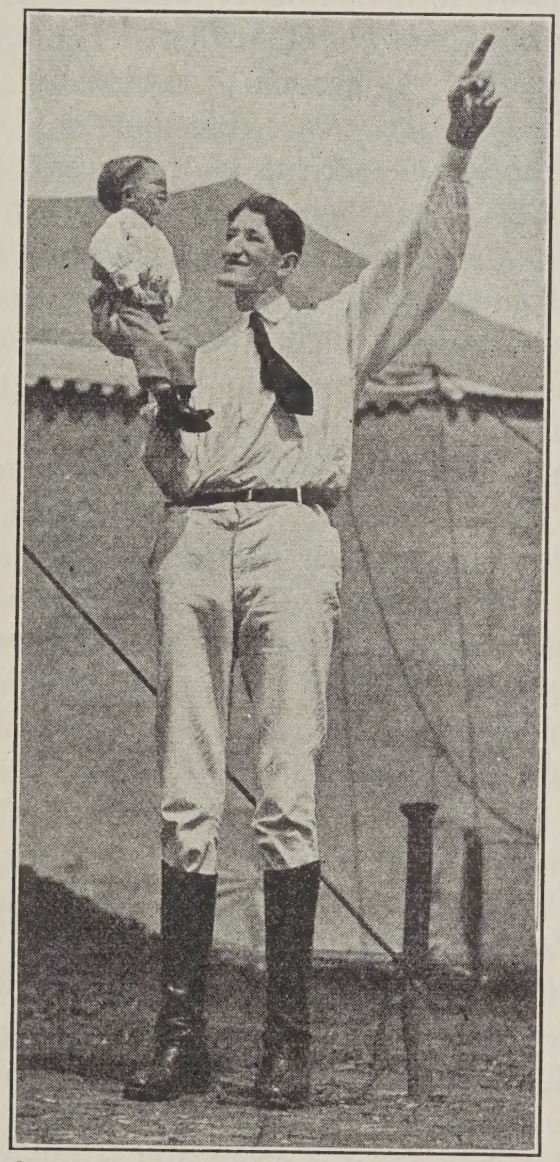


FIG. 351.—Both the giant and the dwarf are victims of the improper functioning of the pituitary gland. (*Courtesy of Ringling Bros. and Barnum and Bailey Combined Circus.*)

needed. Strength for unusual or long-continued exertion is thus obtained.

740. Adrenin, extracted from animals and prepared in laboratories, is sold under the name of "adrenalin." It is used not only

because it releases glycogen but also because it causes involuntary muscles to contract. The walls of the blood vessels contain involuntary muscles, contraction of which controls the blood-flow by making the blood vessel smaller. The use of **adrenalin** in surgical operations is increasing, especially where only a local anaesthetic is used, since bleeding is thereby greatly reduced. This saves the patient an unnecessary loss of blood, reducing the danger from hemorrhages. The more noticeable heart throb that we feel in excitement or fear is due to the action of adrenin which causes the heart, an organ composed of involuntary muscles, to contract. Pallor is due to a contraction of the blood vessels near the surface of the face, preventing the flow of blood through them.

741. Pancreas.—We have noted the secretion of pancreatic juice by a part of the pancreas, thence by a duct into the digestive tract. Glands in another portion of the pancreas, known as the Islands of Langerhans, discharge into the blood stream a hormone which regulates the storage of sugar in the liver. Defective functioning of these glands causes diabetes (*di-ab-e'-tēz*), a condition in which the sugar that is not oxidized readily by the body cells is excreted along with the nitrogenous wastes. The successful treatment of diabetes by introducing extract of sheep's pancreas, led Dr. Banting and other members of the medical staff of the University of Toronto to the production of **insulin** (*in'sū lin*) a form of pancreatic extract. Insulin is now well known and widely used for the treatment of diabetes, as it supplies the deficient hormone of the pancreas. It is usually injected hypodermically by the patient himself before each meal in amounts prescribed by a physician. No one need be greatly incapacitated by diabetes if a **strict diet** is followed, along with the use of the insulin. We should remember, however, that no **cure** for diabetes has yet been discovered, though research is now being carried on toward that end.

742. The Glands of Reproduction.—Like the pancreas, the glands of reproduction are composite duct and ductless glands. Young animals from which these glands have been removed, do

not develop normally. It is well known that male sheep, cattle, and horses become heavier, gentler, less active, and safer to handle, after their removal.

743. In Conclusion.—It is probable that there may be other chemical substances besides the hormones, which are produced by various tissues and turned into the blood stream to regulate other activities, but such substances are extremely difficult to separate from the blood for experimental purposes. Only a vast amount of research in the future can establish the extent to which this theory may be true. Those who hold this view regard the body as being more of a chemically regulated mechanism than has hitherto been supposed.

Interesting Projects

1. Ask your family physician, when you next see him, as to the cause of the unusual development of giants and dwarfs.
2. Look up diabetes in the encyclopaedias. Find out the cause and nature of this disease. Which ductless glands are not functioning normally? What work is normally carried on by the secretion from these ductless glands?

Review

1. How do the ductless glands differ in structure and function from the digestive glands?
2. How do the different hormones affect our development?
3. What life functions do they help to regulate?
4. Why is enlargement of the thyroid gland more likely to arise in localities which are considerable distances inland?
5. When tonsils or adenoids are surgically removed, the danger of hemorrhages may be greatly reduced by applying the extract of what ductless gland? How does this fluid stop the flow of blood?
6. From what source is the substance known as "insulin" obtained? Why are persons suffering from diabetes benefited by the use of insulin?

Define

adrenal gland
adrenalin
adrenin
cretinism
diabetes
endemic goiter
endocrine glands
exophthalmic goiter
hormone
islands of Langerhans
insulin
parathyroid
pituitary gland
thyroid
thymus
thyroxin

UNIT XIII

MAN IS THE ONLY ANIMAL WITH A SOCIAL HERITAGE

CHAPTER LI

MAN'S ABILITY TO PROFIT BY THE EXPERIENCE OF PAST GENERATIONS FORMS THE BASIS OF MODERN CIVILIZATION

744. One of the outstanding characteristics of man in contrast to all other animals is his ability to profit by the past experiences of others. In biology, profiting by the experiences of past generations has resulted in building up a valuable foundation of information concerning the best methods for maintaining good health.

745. Attitudes toward Health.—A great many persons regard health, whether good or ill, as something predestined—something to enjoy or to endure, since it is likely to be either the one or the other. This is not the scientific attitude for us to take. In these days when it is so difficult for a person to realize his ambitions and to carry on his life work successfully, the matter of health is paramount. Is it any wonder that so many of the large corporations require their chief executives to take a medical examination periodically? With the corporation, too, it is a matter of business.

But health is more than a matter of business. It is, to a degree, a requisite to the fullest enjoyment of life itself. We admire the man and the woman who are cheerfully struggling on under a physical handicap. We value their optimism, but how much better it would be for all concerned if the handicap were not present!

This is the day of science, and health, like many other things, should be considered with an open mind and in a scientific attitude. More of us should again read Henley's poem "Invictus" just to be reminded how much it lies within our power to

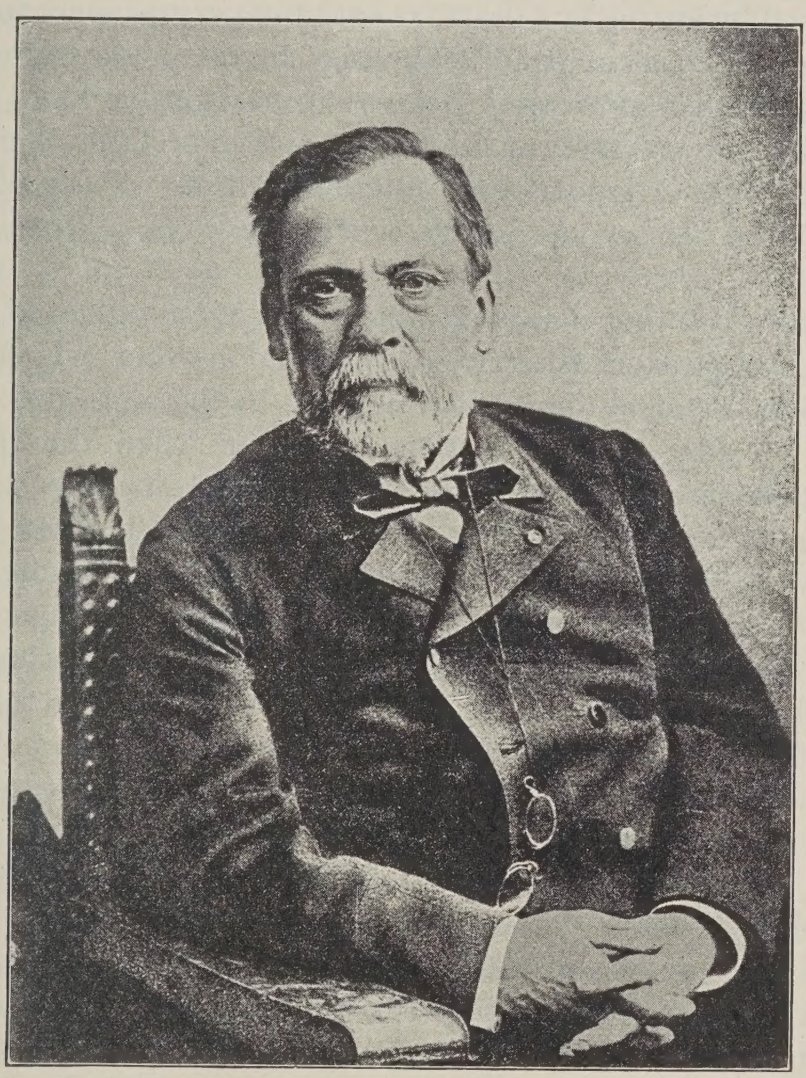


FIG. 352.—Louis Pasteur (1822–1895) was the first scientist to learn that many diseases are caused by micro-organisms called bacteria. (*Corwin and Corwin.*)

maintain health at its best. If we persistently break the laws of nature we always pay the penalty.

746. The Commonest Sources of Physical Discomfort. *Indigestion.*—Probably this is the greatest single source of physical

discomfort. Chapters XLII and XLIII give much help in understanding the causes of indigestion as well as the ways to avoid it.

747. *Colds.*—The common cold, so well known to all of us, is not caused by sitting in a draft, as so many persons seem to think. The "germs" are too small to be seen by the highest powers of the compound microscope. Recent investigations have proved that they can pass even through a porcelain filter, hence the cause of colds is known as a **filterable virus.** These filterable viruses tend to become active when one is in a "run-down" condition.

It is believed that many different kinds of bacteria and viruses enter our respiratory tract at one time and another[1] which do not cause sickness at all; and this brings us to the main point. We should consider a cold as something more than the result of exposure to these particular "germs." A cold should be regarded as an index to our physical condition, for we rarely "catch" cold when we are physically strong and our resistance is high. We should ask ourselves not "Where did I catch it?" but rather, "Have I been getting my full quota of sleep, lately? How about constipation? Have my diet and other health factors been regular?" Usually you will recall the cause. Probably the cold is the result of having disregarded the proper care of the body.

748. A few simple suggestions are given here which, if followed, will help when one has a cold. Eat solids sparingly. Drink several more glasses of water than usual each day. Have fresh air in the bedroom. Keep the skin clean. (The excretory system is thus able to throw off the poisons more easily and quickly.) Take a laxative, if needed. Rest all you can. Retire early and sleep late if possible. Keep away from crowds and do not, through carelessness, give a cold to someone else.

[1] Cultures of bacteria may easily be grown by exposing sterile dishes of culture media, such as agar agar, to mouth scrapings. Seldom do they fail to show the presence of bacteria in the mouth.

749. *Septic Sore Throat.*—The suggestions given above for the treatment of colds generally apply here, also. Gargle the throat several times a day, using any good gargle. Salt and water (a good sized pinch to a cup of hot water) is as good as any, as no gargle ever reaches the back of the throat. It is the heat of the liquid which gives relief.

Cuts.—If a cut is serious, call a physician immediately. Use a tourniquet (See Chapter XLIV) if needed. If the cut is only slight, sterilize it by using any good disinfectant, such as iodine or mercurochrome (*mer-kū'ro-krōm*).

750. *Burns.*—Oil, such as castor oil or sweet oil, or (in the absence of these) even lard will serve to keep out the air and aid in easing the pain. Applications of a paste made from baking soda, to neutralize the acid formed by burns, are often found helpful.

Sprains and Breaks.—Keep the victim quiet and comfortable. Call a physician.

Fainting.—This is caused by an insufficient supply of blood in the head. Lower the victim's head so that the blood will flow into it. If fainting is frequent, a physician should by all means be consulted.

751. Personal Hygiene.—This subject has been defined as intelligent common sense applied to the care of the body. It includes such reasonable care as will enable the body to function normally at all times.

752. You will find it of interest to use the accompanying score sheet in finding the score of your own personal hygiene. Lay a sheet of paper alongside the table below and on it place an "X" opposite each box in which you could truthfully answer "yes". Then add up the total of the grades and thus find the percentage score of your own personal hygiene:

1. Do you bathe at least once a week? ☐ 10 points.
2. Do you consult a dentist every six months? ☐ 10 points.
3. Have you learned to relax? ☐ 10 points.
   (One must be able to discriminate between a good day's work and overwork.)

4. Do you exercise in moderation every day in the fresh air? ☐ 10 points.
5. Do you eat your meals unhurriedly? ☐ 10 points.
   (The consequences of eating hurriedly are as bad as are those of overeating.)
6. Do you wear seasonable clothing, varying its thickness according to the outside temperature? ☐ 10 points.
7. Do you avoid the use of aspirin and other drugs unless taken under a doctor's prescription? ☐ 10 points.
   (The normal body does not need these.)
8. Do you have your bedroom window open at night, much or little according to the severity of the weather, but partly open at all times? ☐ 10 points.
9. In your health habits do you try to live a regular life—not going to extremes about anything? ☐ 10 points.
   (You must be as regular in your health habits as in your social and business appointments if you would be efficient.)
10. Do you follow the advise of the school physician in order to remedy physical defects? ☐ 10 points.

753. Community Hygiene.—This concerns the health of the community of which we are a part. It involves methods of protecting the public in such ways as the following:

Quarantine.—The posting of a warning on the door, making it a legal offense to enter the house where there is a contagious disease, protects **you,** and others, who might enter and contract the disease. One of the evidences of civilization is the careful enforcement of quarantine laws.

Isolation hospitals, where persons having dangerous, contagious diseases are cared for and kept away from others, are one of the many very practical applications of modern medical science.

Compulsory vaccination is another protective practice. Its widespread use shows that the masses of our people recognize its importance.

The State Board of Health has laid down very strict regulations about such matters as the disposal of sewage, the purity of public water systems, and the care of milk sold publicly.

The Federal Pure Food Laws were enacted and are enforced to protect **you** as truly as anyone else.

Public Health Nurses are doing a fine service all of the time, as well as in times of epidemics when their work becomes more conspicuous.

You and I are healthier because of all these measures that have been taken to promote the health of the community.

FIG. 353.—Diagnostic laboratory of a hospital. The work done by the technicians on diseased tissues, serums, blood tests and various analyses enable physicians to diagnose diseases more certainly. (*Photo by U. S. Public Health Service.*)

754. When the Doctor Is Needed.—We can do the most toward keeping ourselves in good health by living normal lives and by giving attention to the proper care of our bodies; but there are times when more scientific knowledge is needed than we possess. Such need arises in all serious illnesses, and when the appearance of certain diseases is suspected. For instance, we need medical aid in cases of severe and repeated nosebleeds, also when the body temperature suddenly runs up above normal, or when chills or repeated nausea are experienced. These are only a few of the times when a doctor should be consulted. The good physician is our friend and should be regarded as such. The inconvenience or expense of seeing him at his office or at our home is usually worth more than the interview costs and will often prevent serious consequences.

755. Attitude toward the Family Physician.—Usually there is some one physician whom our parents have employed in the past. Unless there is good reason to change, we can profit from what he knows of our heredity and our home conditions. The physician is a scientist in the most practical way, and the best physician is often the least expensive in the long run. The laws of our several states have strict requirements for the certification of physicians, requiring much training besides a diploma from a medical school. When consulting the doctor we should cooperate with him to the fullest extent if he is to succeed in helping us. We should give him in detail all information which might aid him in locating the cause of our trouble. Many a family physician is held in the highest esteem by children and parents alike, because of the many valuable and kindly services he has rendered at those times when he was so badly needed.

756. Alcohol and Drugs.—Have you ever read a life insurance policy and thought about the questions that a company always asks a candidate before insuring his life? If not, you would find it interesting to do so. Why are they so exacting as to whether the applicant is a habitual user of alcohol? Why do they insist on knowing whether he has *ever* used intoxicating beverages, and if so, for *how long?* Think this over. With them it is a matter of business. They will not insure at regular rates, men and women whose resistance has been or is being weakened by the habitual use of alcoholic drinks. Such persons are not good "risks"; that is, they are not likely to live the normal length of life and to pay their insurance premiums.

757. By "drugs", as the term is used here, we mean such habit-forming drugs as morphine, heroine, and cocaine. If you have never lost a relative or close friend as the result of this insidious habit, you do not fully realize how serious is the danger. There are two particularly striking phases of the habit when once it is established: first, it destroys the victim's resolution to stop taking the drug; second, in many cases it creates in the victim a desire to induce his friends to try it. I wonder whether Virgil had any of these things in mind when he wrote, more than two thou-

sand years ago: "Easy is the downward path. The gates of hell lie open night and day." If you ever know of any friend who is just taking up this habit of "dope", it is your serious duty to do everything you can to make him realize what his future is going to be.

758. Immunity to Disease.—Have you noticed that some persons are rarely, if ever, sick? There is no doubt that their general resistance is high, but that explanation is not enough. It is now known that certain persons never contract a particular

FIG. 354.—A scientific experiment to determine the cause of disease. The tomato at the left was inoculated with bacteria (*Bacillus corotovorus*) from a diseased tomato. The one at the right was not inoculated. Within four days the upper part of the inoculated fruit was destroyed. (*Atwood.*)

disease, although exposed to it. Such persons are said to be immune to the disease in question. Immunity is defined as a condition of freedom from some specific disease. Immunity of the above type is known as **natural immunity.** Another type, known as **acquired immunity,** is secured either by inoculation, by vaccination, or by having recovered from the disease. After having had certain diseases this protection lasts many years. Smallpox and typhoid fever are examples. Others such as pneumonia and colds may be contracted again and again.

759. Vaccination.—The term vaccination was first used to apply to the inoculation of a person with the virus of cowpox to produce immunity to smallpox. Cowpox, a disease common in cattle is related to the much more serious smallpox. It was

Edward Jenner (1749–1823) who in 1796 proved to the world the value of vaccination, although it had been used by a few individuals before that time. The dread disease, smallpox, was at that time known and feared in nearly every land. The Chinese people had for centuries recorded its ravages. Likewise it had spread to India, Russia, Continental Europe, and, early in the sixteenth century, to America. It probably originated in the Orient. An idea of the seriousness of this disease may be gained from the following extract:

"In 1802 Admiral Berkley, in a speech before the House of Commons said: It is proved that in this United Kingdom alone, 45,000 persons die annually of the smallpox . . . Not a second is struck by the hand of Time but a victim is sacrificed upon the alter of that most horrible of all disorders, the smallpox." And later, "King Frederick William III of Prussia, in a dispatch dated 1803, stated that 40,000 people succumbed annually to smallpox in his kingdom."[1] It is reported that smallpox took a toll of two million lives in Russia in one year. Here in America it is said to have caused the death of six million of the then twelve million American Indians.

760. The results of Jenner's work showed that vaccination did produce immunity to smallpox. As is often the case, people feared the treatment about as much as the disease, although only rarely did anyone have the after-effects of even a very mild attack. In that day people were not as scientifically minded as they now are. Gradually the reports of the many lives saved by immunization spread throughout the world until today in all civilized countries compulsory vaccination is gaining fast headway.

761. "But," people ask, "if vaccination prevents smallpox why are there so many cases of it now? From this one disease thousands of people are dying every year in India, Russia, and China." The answer is simple. These countries do not have compulsory vaccination. If vaccination were uniformly enforced, smallpox could be entirely eliminated. In England

[1] *Americana Encyclopedia*, vol. 25, page 106.

there was less than one case of smallpox among each million persons, until the compulsory laws were repealed in 1898 and 1907. It has now become much more common.

762. Toxins and Antitoxins.—Ever since 1888, when Roux discovered that diphtheria (*dif-ther'-e-ah*) bacilli produce toxins in the body, these toxins have been the subject of continuous study and experimentation. When bacteria die and are broken down, the protein substances present often form violent poisons known as **split proteins.** A toxin is an organic poison, built up by the action of pathogenic (disease-producing) bacteria, or protozoa, within the body of the host. Before long it became known that most of the other diseases, likewise, produce toxins. Since these toxins are so closely associated with the particular disease, and since they are organic poisons, it is only natural that they may be the main cause of the illness.

763. It was the German scientist, Von Behring, who discovered that when blood serum containing toxin of diphtheria was injected into a well animal which had never had the disease, it afterward became immune to it. This led to the discovery that the very presence of the toxin within an animal's body seems to stimulate the body to produce another immunizing substance, to which the name **antitoxin** was given. Today we define an antitoxin as a substance which is produced within the body of an organism, under the stimulus of a toxin.

764. In inoculation today, physicians use attenuated (weakened) toxins and antitoxins. Toxin is used when it is desired to secure immunity to a particular disease by causing the system to build up its own antitoxin. The immunity thus secured usually lasts for a longer time. Antitoxin is often used after a person has already been exposed to the disease and quick immunization is needed, or when the person is not in physical condition to build up his own antitoxin.

765. The commercial production of diphtheria antitoxin is interesting. The antitoxin used in inoculation is not produced in the human body, as is sometimes supposed. Various animals have been used for the purpose. Guinea pigs were used at first.

Goats, rabbits, cattle, and horses have since been used. Today the procedure is usually carried out as follows; a young, healthy horse is selected, and its blood is tested to make sure that the animal is in perfect physical condition. It is kept in a clean stable, under sanitary conditions. Then a small quantity of diphtheria toxin, produced in the laboratory, is injected

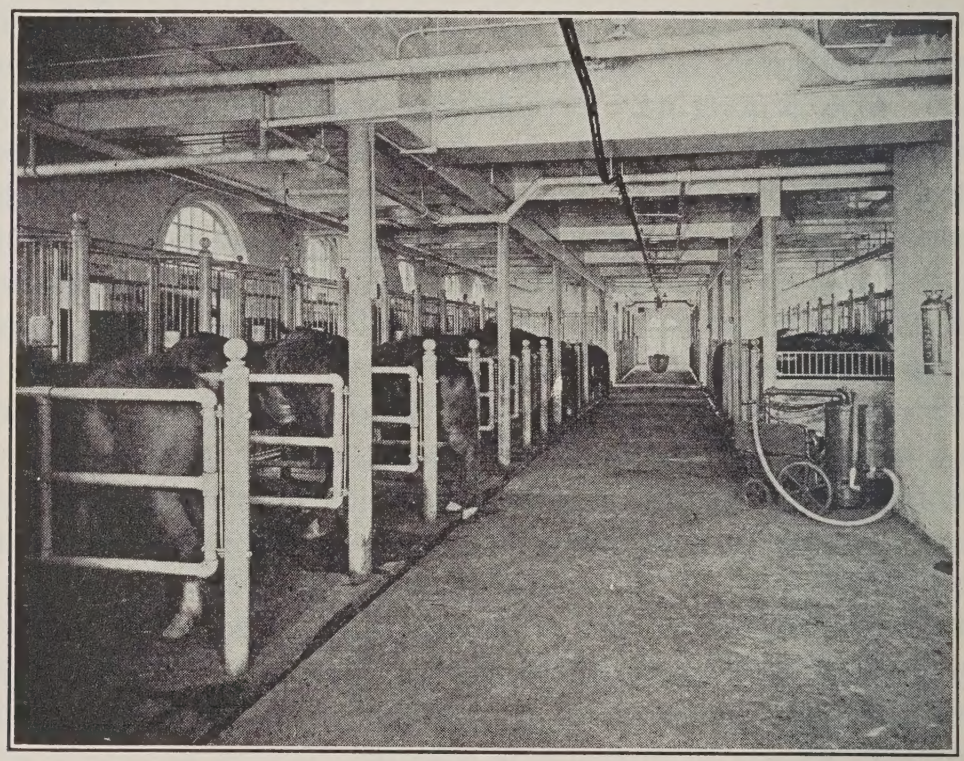


FIG. 355.—Animals used in the production of antitoxins are kept under the most sanitary conditions possible. (*Courtesy Eli Lilly Biological Laboratories, Indianapolis, Ind.*)

hypodermically into the animal's body. As usual, the system responds and produces antitoxin. Again, the same kind of toxin in a larger dose is injected into the animal, and more antitoxin is produced. This procedure goes on for months. Then some of the blood containing the antitoxin is drawn from the horse. It is allowed to clot; the clot is removed, and the clear serum containing the antitoxin, after being tested again for purity, is dispensed by the State Board of Health and by certain pharmaceutical (*far mah sū'tik al*) laboratories—the sources from which a physician can get his supply. In all cases the

absolute purity of the product is guarded as carefully as is its ability to produce immunity.

766. The Schick and Dick Tests.—A child born today has a much better chance for survival than had the child who was born even fifty years ago. Not only has there been marked improvement in sanitation in general, but there are today a great many means of prevention of such diseases as typhoid, diphtheria, and scarlet fever. In scarlet fever and diphtheria, the Dick and Schick tests, respectively, may be used to determine whether a person possesses immunity to these diseases. These tests consist of putting a very small amount of the toxin **into** (rather than under) the skin. The amount of discomfort is no greater than one would receive from a mosquito bite. If a redness of the skin appears around the spot, it shows that the person is not immune, and should be inoculated. (Toxoids are now used for diphtheria.) What an easy way to practice that excellent old adage "An ounce of prevention is worth a pound of cure."

767. Disinfection and Disinfectants.—Infection is defined as the entrance of disease germs (pathogenic bacteria and protozoa) into the body. A disinfectant is any fluid or other substance which destroys such germs. The entrance of the disease germs may take place not only through the nostrils and other body openings, but also through cuts, wounds, and open sores. A whole skin is the only safe condition—unless care is exercised to keep these places disinfected. When we consider how prevalent are the various disease germs, we see at once that all reasonable care should be used to kill those which may have entered at the time the cut or other injury was received. Some of the more common disinfectants used externally are iodine, mercurochrome, and S.T. 37. Few gargles are disinfectants. For cleansing larger areas a solution of lysol or bichloride of mercury diluted to proper strength is effective. As always, extreme care should be exercised in using these drugs, as they are strong poisons.

768. Cancer, Tuberculosis, and Influenza.—Cancer is one of our most serious diseases. At present in this country it is the

cause of one death in every ten among persons forty or more years old. Cancer is a disease of abnormal growth; that is, each cell of a group grows more rapidly than normal, and because of the extra space required a lump is formed. A cancer has been described as "a group of cells gone wild." The mass becomes larger and in time may enter and destroy parts of vital organs, causing death. If at any time you should notice a lump that is slowly becoming larger, or any sore which stubbornly refuses to heal, it should be brought to the attention of a competent physician at once. Only by early attention can cancer be checked. Beware of the quack doctor who offers to cure cancer with medicine. There is no known medicine which will destroy abnormal growths.

769. Pulmonary tuberculosis (*tū ber kū lo'sis*) is a disease of the lungs. The various sanatoria are doing excellent work in curing this disease. Any person suffering from tuberculosis should abstain from all physical work, should rest much of the time in the fresh air, and should include in his diet such tissue-building foods as milk and eggs. Needless to say, in these cases a physician should always be consulted.

A world-wide epidemic of influenza during the World War caused great havoc among soldiers crowded into camps, and war-weary troops in the trenches. The tremendous loss of life concentrated attention on this disease, known in many localities as "the flu", also as "the grippe". The best method to combat it and to prevent its spread is to go to bed in order to give Nature an opportunity to help. It is also wise to use the general sanitary measures, having plenty of fresh air, sunlight, and clean, wholesome food.

770. The Tapeworm and Hookworm Diseases.—These two diseases are caused by the worms whose names they bear. The tapeworm larvae enter the human body in meat not thoroughly cooked. They live in the small intestine, hanging on by tiny hooks and suckers which form on the heads of the worms. As they grow, more and more sections, called **proglottids** (*pro-glot'idz*) are produced. The oldest ones at the end, containing

hundreds of eggs, are discharged with the body wastes. Some of these may reach the ground, and if eaten by grazing animals such as cattle, they migrate by way of the blood stream to the muscles where they encyst. If these muscles, as meat, are eaten by a person or other animal, the life cycle will be repeated.

Tapeworms sometimes reach a length of 30 to 50 feet. Instead of robbing their host of much of his food, they poison him by their

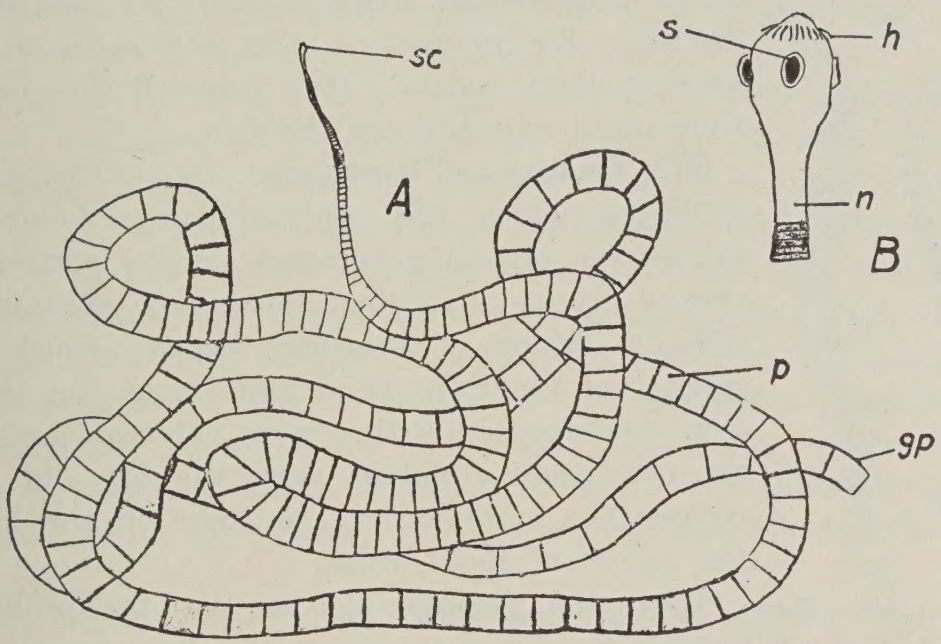


FIG. 356.—Human tapeworm. *A*, the entire animal; *B*, the head or scolex; *n*, neck region; *p*, proglottid; *s*, sucking disk; *gp*, genital pore; *h*, hooks. (*Reese.*)

wastes which react on his nervous system. Tapeworms may be dislodged by the use of oil of chenopodium (*ken o po'de um*) followed by epsom salts, but this method should be used only under the direction of a physician.

771. Hookworm larvae live in moist soil, and when infected soil comes in contact with a person's skin, the worms have the power to bore through it and enter the body. Since low temperatures kill the worms, the disease occurs only in the warm countries. The presence of these worms in the system causes a loss of ambition and initiative. When the worms attach themselves to the intestinal wall, where they feed, they secrete a substance

which prevents the blood from clotting. This causes a constant seepage which is very harmful. Of the 15,000,000 population in Egypt, approximately 60 per cent suffer from the diseases hookworm and bilharziasis (*bil har zi'as is*) (caused by another kind of parasitic worm). The hookworm disease is also prevalent in Jamaica, Java, India, Venezuela, Porto Rico and some other countries. In certain areas of our southern states whole families are stricken with the hookworm disease. The prevention is to wear shoes and to have sanitary toilets. It is believed that infections occur only through the skin.

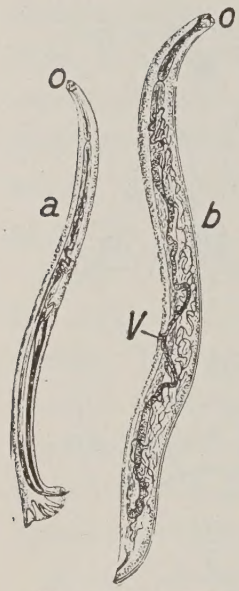


FIG. 357.—The hookworm. *a*, male; *b*, female; *o*, mouth; *v*, opening for discharge of eggs. (*Holmes.*)

772. Quacks and Nostrums.—One of the health problems which has confronted the American people for several generations is the matter of certain types of patent medicines containing different kinds of injurious drugs. Until the passage of the Pure Food and Drugs Act these were taken, often with serious consequences, by the unsuspecting public, since the law did not compel the manufacturer to state on the label the names of these drugs.

With the passage of this law the problem became simpler, since it required the names of the substances in the bottle or package to be printed on the label. But even now the names of such drugs as acetanilide, (*as et an'il id*) codeine (*ko'den*), or atropine (*at'ro pēn*) mean little or nothing to a great number of the people who buy and take these drugs, believing them to be harmless. "The bottles, boxes and cartons containing tonics, ointments and pills were bright with assurances of complete and speedy cures. The fact that most of the results promised could not possibly be accomplished by any drug or combination of drugs yet known to man apparently was completely ignored in framing these labels."[1]

[1] *Hygeia Magazine*, Feb. 1930. Page 132.

773. The presence of habit-forming drugs such as alcohol, heroine and morphine in many of the nostrums has led to the arrest and prosecution of several of their unscrupulous manufacturers. One such false product—and there have been hundreds of different ones—guaranteed to "'soothe crying infants and promote restful sleep.' Sleep induced by morphine is scarcely to be recommended for babies in general, and the soothing effects of this drug might dangerously mask the symptoms of some pathologic condition that should be treated promptly."[1]

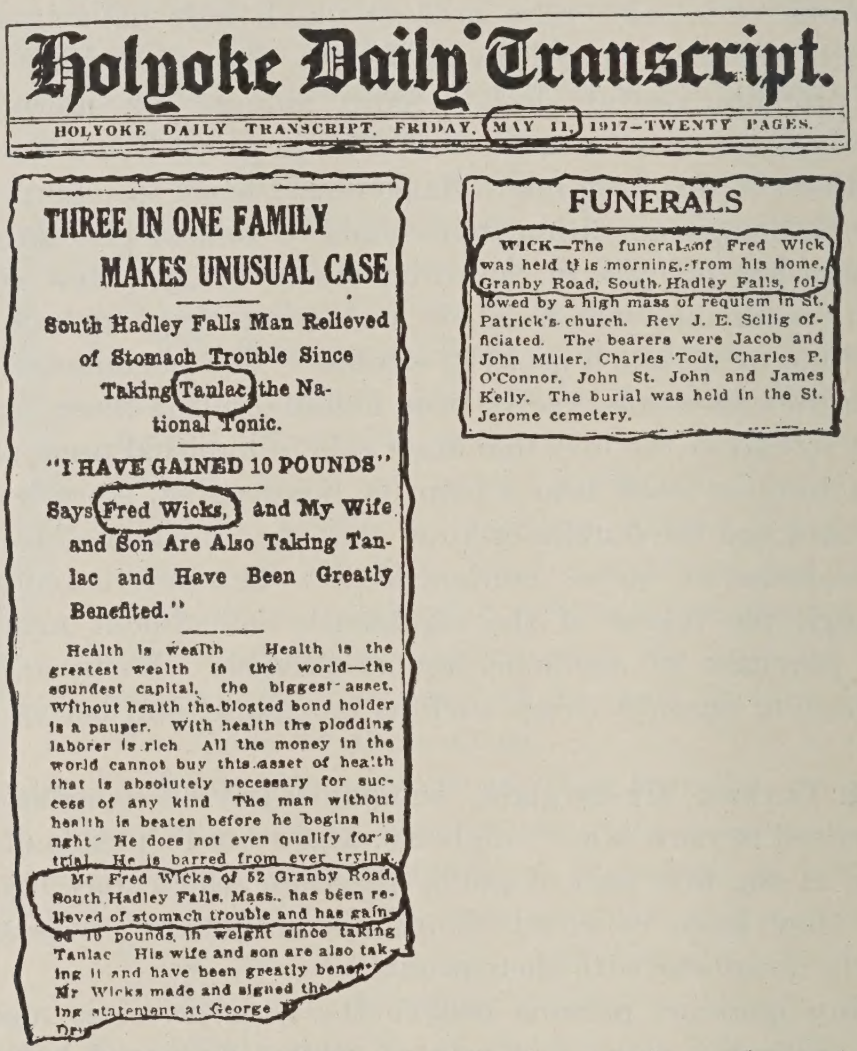
There are on sale in our drug stores today a few of these patent medicines whose labels state that they contain either morphine or as much as 25% alcohol. The phenomenal profit which the charlatans receive from manufacturing these nostrums is not so bad as the fact that their sale to habitual users of these drugs resolves itself into a form of bootlegging, since both the merchant and the purchaser know that the "medicine" is bought for its alcohol or "dope" content alone. This practice continues, although the repeal of the eighteenth amendment makes the legal purchase of alcoholic liquors possible. Fortunately the purchase of narcotic drugs such as morphine, and heroin is still illegal.

774. Certain "fly-by-night" companies put out remedies highly advertised to cure cancer, diabetes, and other incurable diseases. Then, at the first sign of public reaction, which may not come until they have collected thousands of dollars, these quacks quickly disappear with their profits.

Many ignorant persons believe the rash promises made for these nostrums, since it is **printed matter displayed before the public.** In financial affairs we are advised not to purchase questionable stocks and bonds from unknown salesmen. The same principle holds true of drugs. Do not buy questionable nostrums to be taken into your system until you have found out from your family physician, whom you trust, that they are safe.

[1] *Hygeia Magazine*, Feb. 1930. Page 134.

This knowledge of medicines, serums, quarantine, disinfectants, and all that enables us to maintain good health is the result of the work of past generations as well as of medical workers today.



Holyoke Daily Transcript.

HOLYOKE DAILY TRANSCRIPT, FRIDAY, MAY 11, 1917—TWENTY PAGES.

THREE IN ONE FAMILY MAKES UNUSUAL CASE

South Hadley Falls Man Relieved of Stomach Trouble Since Taking Tanlac, the National Tonic.

"I HAVE GAINED 10 POUNDS"

Says Fred Wicks, and My Wife and Son Are Also Taking Tanlac and Have Been Greatly Benefited."

Health is wealth Health is the greatest wealth in the world—the soundest capital, the biggest asset. Without health the blotted bond holder is a pauper. With health the plodding laborer is rich All the money in the world cannot buy this asset of health that is absolutely necessary for success of any kind The man without health is beaten before he begins his night He does not even qualify for a trial He is barred from ever trying.

Mr Fred Wicks of 52 Granby Road, South Hadley Falls, Mass., has been relieved of stomach trouble and has gained 10 pounds in weight since taking Tanlac His wife and son are also taking it and have been greatly bene... Mr Wicks made and signed the ing statement at George ... Dru...

FUNERALS

WICK—The funeral of Fred Wick was held this morning from his home, Granby Road, South Hadley Falls, followed by a high mass of requiem in St. Patrick's church. Rev J. E. Scllig officiated. The bearers were Jacob and John Miller, Charles Todt, Charles P. O'Connor, John St. John and James Kelly. The burial was held in the St. Jerome cemetery.

FIG. 358.—Testimonial and funeral notice in same issue of a newspaper. The American people spend millions of dollars every year for nostrums which have little or no value. (*Used by permission of the American Medical Association.*)

It shows us that the basis of modern civilization is our ability to profit by this experience.

Interesting Projects

1. Read something of the history of the first railroad and steamboat lines. In what ways would our lives today be very different if these two inventions had not been made?

2. From books at your home or in the library learn all you can about man's first homes. What conditions made such homes *desirable* at first, and *necessary* later?
3. Trace, in turn, the different means that man has employed to light his homes artifically, from colonial days down to the present time. Has his ability to profit from past experiences led, each time, to better lighting?

Review

1. How do you account for the much more varied assortment of fruits and vegetables readily available at the corner grocery store now, than could have been obtained twenty years ago?
2. When coming down with a cold, should one try to cure it by taking patent medicines? What is the more reasonable thing to do?
3. What are the two striking characteristics of the "drug habit"?
4. Why is compulsory vaccination gaining fast headway throughout the civilized world?
5. How is diphtheria antitoxin produced commercially?
6. What are some of the principal dangers in the use of patent medicines?
7. Why do the names of dangerous drugs on the labels of certain patent medicines still fail, in many cases, to prevent the public from using them?

Define

acquired immunity
attenuated toxin
Dick test
disinfectant
inoculation
infection
natural immunity
pathogenic bacteria
pharmaceutical laboratory
quarantine
sanitation
serum
Schick test
split proteins
toxins
toxin-antitoxin
vaccination

CHAPTER LII

THE SCIENCE OF BIOLOGY WILL CONTINUE TO MAKE ITS IMPORTANT CONTRIBUTIONS TO HUMAN WELFARE AND PROGRESS

775. It is only with the greatest caution that one may safely forecast the future of any science. Certain trends may be noted, such as the application of the laboratory method to scientific problems, or the development of new domesticated varieties of plants and animals by selection and hybridizing. But to predict the exact course a science will take is impossible. Who, for example, two hundred years ago, would have dared to predict an end to the scourge of smallpox or the remarkable results of modern surgery? Seventy-five years before the present successful development of food plants and modern farm machinery it was believed that, as a result of over-population, famine would overcome the world by the year 1900.

FIG. 359.—Hideyo Noguchi (1876–1928) developed anti-venin serum for the bite of poisonous snakes. While still a young man he lost his life in an attempt to find a method of control of the African type of yellow fever. (*Courtesy of The Rockefeller Foundation.*)

This progress in biology, due primarily to the intelligent application and coördination of the facts of an ever-increasing body of knowledge, is subject to the occasional genius of a Vesalius, a Darwin, a Pasteur or a Mendel which may profoundly change the course of development of the science.

776. The remarkable success of medical science in its struggle against the biological diseases tempts the prediction that at some future period all diseases caused by parasitic plants and animals will be brought under control. Abnormal growths, which are baffling the combined efforts of the most highly skilled scientists may perhaps await more knowledge concerning the methods of cell growth, before they can be conquered. We find that mental diseases, once believed to be manifestations of evil spirits, and

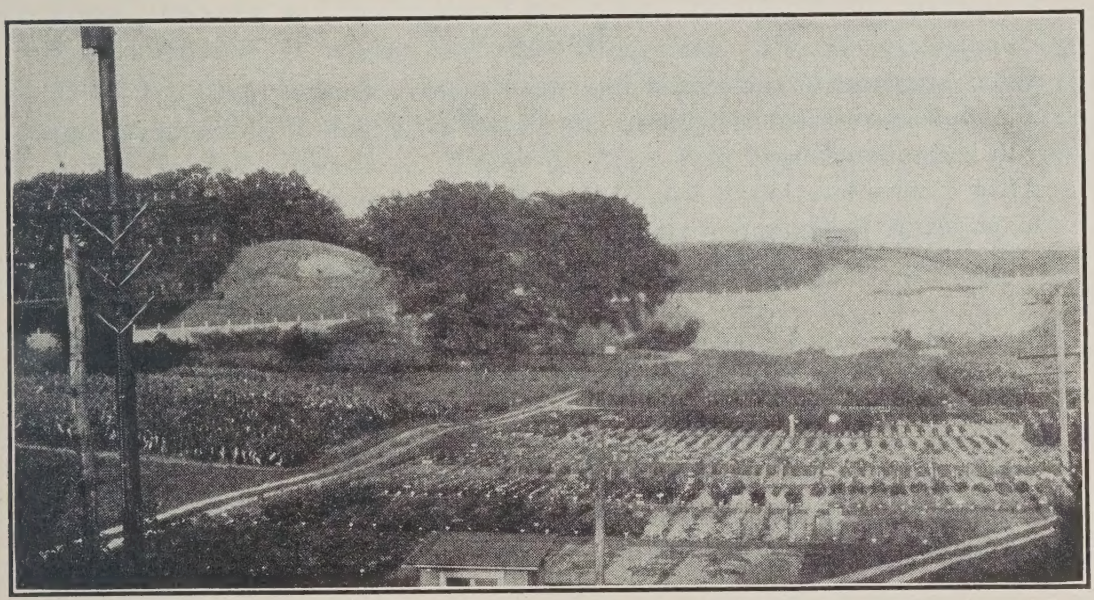


FIG. 360.—Many new and better kinds of fruits and flowers are developed in gardens such as this which are used for experimental purposes. (*Photo by The U. S. Dept. of Agriculture.*)

barbarously treated as a consequence, now receive relief from methods based on a scientific study of underlying causes. This war against disease is being waged relentlessly and successfully on many battle fronts. Civilization will not permit the struggle to end until every child has its birthright of a life-span free from disease and the suffering that it brings.

777. Besides human disease, we find many other challenges to the ingenuity of the mind of man. There are plant diseases and insect enemies which must be controlled if we are to have an adequate food supply. Better varieties of fruits and flowers are profitable to those who develop them and they add to the

comfort and enjoyment of many. Newly discovered biological facts may become of the greatest importance. Pasteur's discovery that many diseases are caused by micro-organisms was simply an interesting scientific fact until methods were devised to make use of this knowledge. Recruits are constantly being trained for the front line, but disease and ignorance are firmly entrenched, and a place is assured for every worker who is thoroughly trained and resourceful.

Review

1. What are some of the past achievements in the field of biology?
2. Which scientist is most closely associated with each of the achievements you have mentioned?
3. After a consideration of what has already been accomplished in biology, what future achievements do you consider to be possible?

APPENDIX A

BOOKS YOU WILL WANT TO READ

AKELEY, CARL. **Africa.** Blue Ribbon Books.

ALLEN, ARTHUR A. **The Book of Bird Life.** D. Van Nostrand Co.

ALLEN, GLOVER M. **Birds and Their Attributes.** The Marshall Jones Co.

ANDREWS, ROY CHAPMAN. **Across Mongolian Plains.** Blue Ribbon Books.

ANDREWS, ROY CHAPMAN. **Ends of the Earth.** Blue Ribbon Books.

ANDREWS, ROY CHAPMAN. **Whale Hunting With Gun and Camera.** Blue Ribbon Books.

BARBOUR, THOMAS. **Reptiles and Amphibians.** Houghton Mifflin Co.

BARRETT, JOHN. **Panama Canal: What It Is; What It Means.** Pan American Union.

BEEBE, WILLIAM. **The Arcturus Adventure.** G. P. Putnam's Sons.

BEEBE, WILLIAM. **Edge of the Jungle.** Garden City Publishing Co.

BEEBE, WILLIAM. **Jungle Days.** Garden City Publishing Co.

BEEBE, WILLIAM. **Jungle Peace.** Modern Library, Inc.

BEEBE, WILLIAM. **Nonsuch.** Harcourt, Brace & Co.

BLANCHAN, NELTJE. **Bird Neighbors.** Doubleday, Doran & Co.

BLANCHAN, NELTJE. **Birds That Hunt and Are Hunted.** Doubleday, Doran & Co.

BLANCHAN, NELTJE. **Nature's Garden.** Doubleday, Doran & Co.

BLANCHAN, NELTJE. **Wild Flowers Worth Knowing.** Doubleday, Doran & Co.

BROADHURST, JEAN. **How We Resist Disease.** J. B. Lippincott & Co.

BYRD, RICHARD E. **Skyward.** G. P. Putnam's Sons.

CHAPMAN, FRANK M. **Handbook of Birds of Eastern No. America.** D. Appleton-Century Co.

CHAPMAN, FRANK M. **The Travels of Birds.** D. Appleton-Century Co.

COMSTOCK, A. B. **Handbook of Nature Study.** Comstock Pub. Co.

CROWDER, WILLIAM. **A Naturalist at the Seashore.** D. Appleton-Century Co.

DANA, MRS. WILLIAM STARR. **How to Know the Wild Flowers.** Chas. Scribner's Sons.

DEKRUIF, PAUL. **Hunger Fighters.** Blue Ribbon Books.

DEKRUIF, PAUL. **Microbe Hunters.** Harcourt, Brace & Co.

DITMARS, RAYMOND L. **The Reptile Book.** Doubleday, Doran & Co.

DITMARS, RAYMOND L. **Confessions of a Scientist.** The Macmillan Co.
DICKERSON, M. C. **The Frog Book.** Doubleday, Doran & Co.
DORSEY, G. A. **Why We Behave Like Human Beings.** Blue Ribbon Books.
EAST, E. M. **Biology in Human Affairs.** McGraw-Hill Book Co.
FABRE, J. H. **The Life and Love of the Insect.** A. and C. Black, Ltd.
FERNOW, B. E. **The Care of Trees.** Henry Holt & Co.
GREAVES, J. E. & E. O. **Elementary Bacteriology.** W. B. Saunders Co.
GUYER, M. F. **Being Well Born.** The Bobbs-Merrill Co.
HARROW, BENJAMIN. **Vitamins.** E. P. Dutton & Co. Inc.
HOLLAND, W. J. **The Butterfly Book.** Doubleday, Doran & Co.
HORNADAY, W. T. **American Natural History.** Charles Scribner's Sons.
HORNADAY, W. T. **Minds and Manners of Wild Animals.** Ch. Scrib. Sons.
HOWELL, W. H. **Textbook of Physiology.** W. B. Saunders Co.
JORDAN, D. S. **Fishes.** D. Appleton & Co.
LOCY, W. A. **Growth of Biology.** Henry Holt & Co.
LOCY, W. A. **Biology and Its Makers.** Henry Holt & Co.
LUCAS, FREDERICK A. **Animals of the Past.** American Museum of Natural History.
LULL, R. S. **Ancient Man.** Doubleday, Doran and Co.
LUTZ, F. E. **The Field Book of Insects.** G. P. Putnam's Sons.
MATHEWS, F. S. **Field Book of Wild Birds and Their Music.** G. P. Putnam's So.
MATHEWS, F. S. **Field Book of Am. Trees and Shrubs.** G. P. Putnam's S.
MATHEWS, F. S. **Field Book of Am. Wild Flowers.** G. P. Putnam's Sons.
MAYER, ALFRED G. **Seashore Life.** A. S. Barnes & Co.
MCCOLLUM, E. V. & SIMOND N. **Food, Nutrition and Health.** Dr. E. V. McCollum.
MCCOLLUM, E. V. & SIMOND N. **Newer Knowledge of Nutrition.** Macmillan.
MIX, JENNIE I. **Mighty Animals.** American Book Co.
NORTHROP, A. R. **Through Field and Woodland.** G. P. Putnam's Sons.
OSBORN, H. F. **From the Greeks to Darwin.** Charles Scribner's Sons.
PACK, CHARLES LATHROP. **School Book of Forestry.** J. B. Lippincott & Co.
PACK & GILL. **Forests and Mankind.** The Macmillan Co.
REED, CHESTER A. **Bird Guide—Land Birds.** Doubleday, Doran & Co.
REED, CHESTER A. **Bird Guide—Water Birds.** Doubleday, Doran & Co.
ROBINSON, J. H. **Mind in the Making.** Harper Bros.
ROOSEVELT, THEODORE. **East of the Sun and West of the Moon.** Blue Ribbon Book.
TRANSEAU, E. W. **General Botany.** World Book Co.
VALLERY-RADOT, R. **Life of Louis Pasteur.** Doubleday, Page & Co.

WALTER, H. E. **Genetics.** The Macmillan Co.
WEED, C. M. **Our Trees, How to Know Them.** J. B. Lippincott Co.
WIGGIN, A. E. **Exploring Your Mind.** Blue Ribbon Books.
WIGGIN, A. E. **Fruit of the Family Tree.** Bobbs Merrill Co.

APPENDIX B

Classification of Birds

The new orders and arrangement now adopted by the American Ornithologists' Union are as follows:

Gaviformes	Loons
Colymbiformes	Grebes
Procellariiformes	Albatrosses, shearwaters and petrels
Pelicaniformes	Pelicans, cormorants etc.
Ciconiiformes	Herons, flamingoes etc.
Anseriformes	Ducks, geese, and swans
Falconiformes	Vultures, hawks, and eagles
Galliformes	Grouse, quail, turkeys etc.
Gruiformes	Cranes, rails etc.
Charadriiformes	Sandpipers, plovers etc.
Columbiformes	Doves and pigeons
Psittaciformes	Parrots
Cuculiformes	Cuckoos
Strigiformes	Owls
Caprimulgiformes	Goatsuckers
Micropodiformes	Swifts and hummingbirds
Trogoniformes	Trogons
Coraciiformes	Kingfishers
Piciformes	Woodpeckers
Passeriformes	Perching birds

This classification has been worked out on the basis of true relationships and has been accepted by all countries. For details, see the **Check List of North American Birds,** fourth edition, published by the American Ornithologists Union, 1931.

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